NUCLEAR INDIA

~~1974-76~~

~~VOL 13-14~~

VOL. 12 — 1974

55

CFTRI LIBRARY
No 55
Date
MYSORE-2A.

NUCLEAR INDIA

Republic Day Special

January 26, 1974

CENTRAL LIBRARY
MYSORE 2A
15 SEP 1975

NUCLEAR INDIA

Republic Day 1974

The attention devoted to science and technology today is perhaps unprecedented in the country's history. There is a continuing debate on policies, investments, R&D, and the contribution of the scientist and the technologist to the developmental effort. The Approach Paper circulated by the National Committee on Science and Technology last year was an attempt on a national scale to draw out and give direction to informed opinion in this area. Nationwide discussions of the paper among scientists, technologists, industrialists, educationists, sociologists, economists and others helped in defining goals, setting objectives and formulating the science and technology plan as part of the Fifth Five Year Plan.

The scientists and technologists of the Department of Atomic Energy have made significant contributions not only to specific disciplines but also to the culture and thinking on research and its applications. To mark the 24th anniversary of India as a Republic we invited them to contribute their views and opinions over a broad spectrum of subjects. Not all of them were available, or could find time to write specifically for this issue. But as they have often spoken out and written at other times and places, we have included excerpts from their articles and speeches which reflect their thinking. We thus present not so much a review of the activities of the Department, as views and opinions on diverse issues of interest to them.

The Chairman of AEC, Shri H. N. Sethna, considers the problem of the degradation of the environment, holding that not science and technology in themselves, but their short-sighted and unenlightened use by man which is responsible for the problem. The environment is also the subject of Shri P. R. Kamath's article. Shri Kamath maintains that the problem of environmental pollution in India is not the same as that in industrialised nations. India is not at all a highly populated country if only population densities are compared. He advocates a development strategy where the production programmes are integrated with programmes for the protection and conservation of the environment.

Dr. R. Ramanna poses a question about the strange contradictions in the Indian scientist, and attempts to analyse his motivations and attitudes against the background of traditional values the Indian scientist has grown up with.

Shri A. S. Rao in this special article is uncompromising on his stand about foreign collaboration in India.

Dr. M. R. Srinivasan describes the progress towards indigenisation in the nuclear power programme, and gives an idea of the efforts made by Indian engineers and the industry to meet the demands of this advanced technology.

The fast breeder reactor holds an important place in the country's nuclear power strategy and Dr. P. K. Iyengar talks about it and explains the work that is going on in this area in India. Drs. K. Sundaram and R. D. Ganatra discuss the development of nuclear medicine and its present-day status in the country.

The mechanisms for repair of the DNA, almost always the genetic material of all living organisms, is discussed by Dr. A. R. Gopal-Ayengar who suggests that DNA repair may have governed the rate of evolution of all species by protecting, preserving and changing DNA from prebiotic times to the present day. Dr. A. Sreenivasan talks about the contribution of the physical sciences in the understanding of biological phenomena and holds that with the inflow of these sciences into the realm of biology, there will be deeper understanding of their fundamental laws.

CONTENTS

The Degradation of the Human Environment — A Consideration of the Role of Technology	3	*H. N. Sethna*
Environmental Strategy for Development	6	*P. R. Kamath*
Developing on Our Own	11	*A. S. Rao*
The Promise of Fast Breeder Reactors	14	*P. K. Iyengar*
Towards Self-Reliance in Nuclear Power	18	*M. R. Srinivasan*
Inflow of Physical Sciences into the Mainstream of Biological Concepts	23	*A. Sreenivasan*
The Story of DNA Repair	27	*A. R. Gopal-Ayengar*
Nuclear Medicine : 25 Years	30	*K. Sundaram & R. D. Ganatra*
The Philosophical Motivations of a Scientist	33	*R. Ramanna*

The Degradation of the Human Environment— A Consideration of the Role of Technology

WE have reasons today to be concerned about the degradation that is coming about in the physical environment of man, especially in the industrial and metropolitan areas. This is at a time when science and technology are holding great promises for man's prosperity and well-being. Here I should like to consider the problem in perspective and in the context of human needs and desires.

We thought in this country, as in other countries, that the solution to physical problems of man lie in science and technology. This I firmly believe to be much more true today than it was, say a few decades ago. The present day criticism of science and technology in certain quarters is also an emotional response to the problems of degradation of the human environment — stated as due to the growth of science and technology. Social or human response of this kind, specially in this country, also concerns us.

It has to be conceded that man and his society developed from primitivity primarily through his incessant efforts to mould a hostile natural environment into a benign one. There is no question of going back to that nature. Initially man might have had the prime motivation of survival to contest the elemental forces; then after appreciating the physical nature of such forces, he started to influence or condition his immediate environment. Further on, he aspired to mould and exploit the global environment for his living and betterment. The guiding spirit through these stages had been the progressive development of a value sense, either intuitive or analytic, and the pathfinder for the realisation of such values must have been his intelligence. Science and technology, the latter-day offsprings of his intelligence dealt in their applications with problems of path-finding in a rational manner and according to the dictates of his requirements and value sense.

Values as conditioned by environment and history are characteristics of the mosaic of human cultures, whereas the inner content of scientific and technological processes appears as universal. I made this distinction in order to emphasise that with the growth of science and technology, man has not been able to develop a rational wisdom to deal with his value sense or his short-term and long-term interests. Exploitation of the natural resources and environment to meet the short-term interest of man has been in my understanding the most common feature of human societies. Our sense of self-interest is perhaps not as enlightened as we thought it is for us and for our progeny. The universal concern today for the degradation of human environment is the enlightened reaction of intelligence against the short-sightedness of thoughtless interference with his environs. All what has happened or is happening is not necessarily due to science and technology.

Let me cite a few mundane problems in life and living to illustrate the point. Water-borne epidemics or air-borne infectious diseases or carrier-borne endemic diseases have been demonstrated to be eradicable and we do desire to eradicate them. If this is not obtained in our societies, it is to be understood as a sociological and human management problem.

During the last decade we have been witness to the concern expressed in industrialised countries as well as in this country about environmental degeneration in various ways. Those that are technological in origin, as in many areas it has been found to be, have been demonstrated to be well within the bounds of science and technology to arrest the decline and even improve upon. The comparatively clean air conditions that have been obtained in smog bound cities like London, Pittsburgh or New York are examples in point. Scientific or technological solutions to the problems were mostly known before hand, the welcome changes were brought about by planning, legislative action and enforcement. There are no indications that the economy of these areas suffered as a consequence of such actions.

Man has been exploiting various natural resources for meeting his increasing demands for energy. When fossil fuels are used as sources of power, they generate large quantities of residuals and toxins. For a thermal station using coal as fuel — for each KW of electrical energy generated, the annual consumption of coal is about 2.5 tonnes. The residues and toxins of major concern from such plants are fly-ash, smoke, soot and gaseous oxides of Sulphur, Nitrogen and Carbon. The annual estimated release from a 400MW electrical plant using coal is about twenty thousand tonnes of sulphur dioxide, about eight thousand tonnes of oxides of nitrogen, about two hundred tonnes of carbon monoxide and around two thousand tonnes of particulates. If the thermal generation capacity in the country is to treble in the near future, coal consumption for this purpose is expected to rise to about 50 million tonnes per annum. The problem is how to deal with the staggering quantities of wastes and toxins that will be generated.

The basic principle of wastes management, as in nuclear energy, should be one of containment at the source. Wastes or toxins once discarded into environment are irretrievable and it is well-nigh impossible to trace or estimate the damage even with diligent surveillance techniques. For that part of the effluent that cannot be contained, the principle of dilution and dispersion can be followed, so that when it reaches the public, these toxins are already diluted and dispersed well below the safety level. There exists in such a parameter the 'safe recipient capacity' for a given environment and its ecological chain of which man himself is a component link. The sizes or complexity of industries and human habitation and their needs are such that the rejects or wastes discarded today, in many cases far exceed the environmental capacity. Ecosystem and the physico-chemical characteristics of the environmental components are such that these have a great in-built capacity, which is not unlimited, of clearing the water, air and soil from most of toxins. Our capacity today of generating such toxins, specially in metropolitan areas, far exceeds this limit. Safe recipient capacity of an environment is a scientifically determinable quantity — *a priori*. In my view this is the most important parameter to take cognisance of either for planning of industrial sites or for habitation.

In the light of our experience in Atomic Energy, we believe that environmental pollution control and demonstration of conformance to set norms are parts of operational or waste generators' responsibilities; surveillance or monitoring of such conformance resting with public institutions including autonomous governmental agencies.

In our efforts and hope to raise the standard of life and living we also produce as wastes a number of chemicals and other materials which are alien or toxic to the environment. Examples in point are : Mercury, Lead, Cadmium and their compounds, halogenated hydrocarbons and the large variety of organo metallic pesticides. Matrices of the environment cannot detoxify these and to make the situation worse, the eco-system often concentrates these toxins in many of the products harvested by man as food. Extensive R & D programmes are on hand to develop new products that are biodegradable to innocuous matter; till such time we need to have very cautious national policies on the use of these otherwise very useful alien compounds. It is in the final analysis a question of balancing the risk-benefit equations.

Another problem in the present-day society is the wasteful utilisation of natural resources and the attendant degradation of human environment. I take the example of the paper and pulp industry, an essential one in human societies. The total volume of liquid effluents disposed of from such industries accounted for 15% of the total industrial effluents in USA in 1969. The American Paper Institute reported that each ton of recycled paper saves about 17 big trees. Even a partial recycling of paper (about 20%) in the US, where the average annual consumption of paper is about 576 lbs per person amounts to 11.4 million tons, representing a saving of nearly 200 million trees. This demonstrates how a recycling technology can help to conserve the resources and in the process reduce environmental degradation. Technology is well established, the solution however lies with planning and organisation.

As an example of our own unintended deforestation efforts we have often seen that site development for a large project, means extensive felling of forest trees, without a planned compensatory aforestation. This happens even when we are actually aware of the deleterious effects of such practices. This in my mind is not so much of a scientific or technological problem as that of social education, legislative enactment and enforcement of laws.

Objective consideration of environmental factors for

iting of industrial units have not received so far the veightage they should. Even expansion or relocation of xisting facilities or addition of other units in an indus-rialised area need to be planned with due consideration of nvironmental factors. We need to move away from the arlier approach when industries were developed and locat-d before environmental hazards were understood in pers-pective. Corrective measures incorporated subsequent to iting an industry did not often meet the requirements of nvironmental safety. Taking the example of a thermal ower station again : to escape being labelled as a sulphur lioxide pollutive industry, a 400 MWe thermal station using oal of 2% sulphur content, the exclusive plant area dis-inctly separated from public domain works out in many egions of the country to be in excess of one mile. We need to take into account such evaluation till we discover better methods of containing sulphur dioxide. Similar emarks can also be made in respect of many other conven-ional industries.

Industrial expansion has drawn the working class population to urban and suburban areas leading to a dis-proportionate development of human settlements and slums, creating complicated and uncontrolled municipal problems. We have an enormous strain on fresh water supplies and all cities are starved of adequate fresh or clean water supplies. People live in unhygenic conditions with impro-per and inadequate sanitation adding progressively to pollution and diseases. Again I recognise this as a problem of planning, distribution and management.

I have chosen my examples in this vast area of human concern somewhat randomly. I wish to conclude with a working definition of pollution with all its implications :

> *a state of pollution in the environment is recognised as resulting from human activities when the residues and toxins which are generated reach man in excess of normal, natural concentrations which makes the environment unsafe for healthy living and normal pursuits, or affects adversely the utilisation of environmental resources for human benefits and enjoyment.*

(Excerpted from the speech delivered at the Raj Bhavan, Bombay at a Seminar on Ecology, Environment and Man on January 16, 1974.)

P. K. Kamath
Head, Environmental Studies Section,
Bhabha Atomic Research Centre, Trombay.

Environmental Strategy for Development

'Then the ocean spoke thus :

I am very expansive and very large, and in me are born many many animals and creatures. Therefore I always wish that my form should be very clean. If I give place to dirt, though it be very small, tomorrow it will make all my forms unclean'.

Summer Showers 1972

THERE is an optimal size for the growth of a city and an industrial establishment in relation to its environment as much as there is a limiting number for the size of a family for happy living. When the limits are exceeded for any reason the efforts to promote the well-being of the community will work to its disadvantage.

The minimum requirements for healthy habitation in a city are the following : fresh air and sunshine, treated water supply, sewers and drains, systems for treatment and disposal of sewage, garbage and refuse. Industrial zones can be many but should be segregated from residential areas. Transport, schools and hospitals should be within reach and conforming to sanitary requirements. Patches of greenery and open areas should be interspersed between groups of buildings to reduce congestion.

Health of a community is not merely an absence of disease but a state of physical, mental and social well-being. (*WHO Geneva, Basic Documents 1963*).

Domestic Waste

THE supply of drinking water throughout the day is a basic minimum for sanitary living. Water is required for drinking, cooking and bathing and to wash away waste products in the homes. The availability of regular water supplies should be a guide to set the limits for the growth of a city and its industry on the basis of adequate supply of water throughout the day. Water supply gets polluted through many routes of which land wash in rainy seasons, and discharge of sewage effluents are the principal ones. Even on treatment of the sewage, effluents contain rich nutrient pollutants which can damage a water source by algal growth and eutrophication. Contamination of drinking water can also take place in storage and piping.

The faeces of man contains a large number of pathogens which can cause epidemics. Water-borne diseases like infective hepatitis, poliomylitis, amoebiasis, cholera, gastroenteritis, typhoid and other intestinal disorders are attributed mainly to faecal pollution of drinking water. In the populated developing countries, pollution of water supply from domestic wastes far outweighs contaminations from trade effluents in magnitude and toxicity. The deterioration of water quality and inadequate supply in cities have ceased to arouse public protests. Instead, the attention has shifted to the direct and visible effects of industrial effluents.

Urbanisation

INDUSTRIAL growth is essential for the progress of the community and harnessing of national resources. Fears of pollution from the discharge of trade effluents are unwarranted in this country because of the size and untapped resources and harmful to its progress.

Industrialisation in this country means job opportunities; people migrate to industrial sites in search of jobs. Labour hutments appear at the site followed by shops and canteens. A new pollution centre is gradually built up with its slums, open drains and sullage. If the industry releases, in addition, its waste effluents without treatment and control, a nearby water source gets contaminated.

The health and safety criteria for locating large installations like a power station or industrial complex should take into consideration the distances to which the waste effluents may drift in air and water, dispersing pollutants at unacceptable concentration levels. The objective of defining site boundary limits is to ensure that no one outside the boundary is exposed to pollutants of site origin in excess of the permissible intake. (*Health and Safety Criteria for Siting Power Reactors in India — IAEA Symposium, Bombay 1963*).

In most countries siting limits are evolved on the basis

of releases to air. With the adoption of air cleaning devices in industry and increasing concentration of pollutants in aquatic organisms and silt it will be necessary to consider also the behaviour and toxicity of pollutants in the aquatic environment.

Given the will, pollution in an industrial area can be kept down through technology, recovery of residuals, change of process, shifting of a sick unit, and by administrative and legal measures. The right course is to plan from the beginning, starting with proper criterian for selection of the site.

Radioactive effluents for example are probably the most rigorously controlled trade effluents because of the stringent permissible limits in air and water. Permissible concentration limits in water for some radionuclides are compared below with those of stable isotopic toxins.

Pollutant	Max. Allowable Concn mg/1 (ppm) stable	Max. Permissible concentration mg/1 (ppm) radioactive
Arsenic (As)	5×10^{-2}	9.2×10^{-12}(As-76)
Cadmium (Cd)	1×10^{-2}	4.6×10^{-11}(Cd-115)
Copper (Cu)	1	6.2×10^{-11}(Cu-64)
Lead (Pb)	5×10^{-2}	1.1×10^{-9}(Pb-210)
Manganese (Mn)	5×10^{-2}	1.2×10^{-8}(Mn-54)

i) *Exclusion Area*

A nuclear power station is located away from large cities. A distance of upto 1600-2400 metres from the station is accepted as the site boundary. The exclusion zone is primarily meant to prevent exposure of population. It provides a cushion for management in any untoward production of waste. Any extra space available can be used to install supporting units, provided the new units do not add to the pollution burden on site.

ii) *Sterilised Area*

A low population zone upto 5,000 metres from the station is defined as a sterilised area where it would be necessary to exercise certain control in the overall expansion of public activities.

USSR Practice

There are however no restrictions recommended on public activities in the sterilised area at the chosen sites in India except in one instance where expansion of salt pans close to the outfall is not considered advisable because of the possible carryover of contamination, however small.

In the Soviet Union, the size of the protective zone of separation between industrial enterprises and residential areas depends on the harmful substances discharged to the environment.

The zones are classified by the nature of the production process, effectiveness of pollution control and local conditions. The width of the protection zone ranges from 50 metres upto 3,000 metres, which may be increased further, if in addition to atmospheric pollution there is the fear of fire or explosion. (*WHO Report no. 297, 1965*)

Some examples of sanitary protection zones are given below : (*USSR Literature on Air Polllution and related occupational diseases, 1948 Vol. 4 US translation*)

Production of bound nitrogen & agricultural fertilisers	2,000 metres
Processing of natural refinery gases and allied products	2,000 m
Production of sulphuric acid	200 m
Production of rare metals by the chlorination process	1,000 m
Production of chromium & lead paints	1,000 m
Building of accumulators on small scale	100 m

Large installations with protective zone width in the 1,000 m range are required to be located beyond the city limits. The hazard of siting even with such restrictions may arise where there are programmes for expansion or addition of waste producing units on site. In such cases in USSR 'if for some reason it is impossible to implement efficient effluent control measures, and the discharges from the industrial establishment affect unfavourably the living conditions in the area, the sanitary epidemiological service may require that the whole factory or part of it be transferred to another locality' (*Inter-regional conference on Air Pollution Control, Moscow, 11-20 Sept. 1967*).

Other Alternatives

IN smaller geographical states with a high density of industrialisation, such protective zoning or exclusion may not be feasible. Technological solutions for containment, transfer or replacement of sick and hazardous units, alterations to a process may have to be considered as suitable.

It has to be however borne in mind that it is possible in an industrial complex for unexpected production of a large volume of effluent following the breakdown of a component and unit operation. Free space comes handy

in such cases to hold wastes for subsequent treatment instead of effecting a panicky release to the environment. Situations of this kind may be met with where familiarity with design, maintenance and operational practices is still to be acquired. In importing technology it is necessary to collect experience of waste management.

It should be necessary in the first instance to carry out an evaluation of design and process for generation of wastes and demonstrate methods of wastes containment before an authorisation is given to locate the industry. Ideally, the design should provide for total containment of wastes because wastes once discharged are not retrievable. Discharges made at permissible concentration limits in air and water are not necessarily safe because of the processes of reconcentration in the environment. A project should be evaluated therefore in the context of its environment.

Studies at Nuclear Sites

ENVIRONMENTAL monitoring and investigations at a nuclear site are carried out right from preoperational stage in the Environmental Survey Unit (ESU) consisting of the micrometeorological and surveillance laboratories. Micromet observations are carried out from a tower equipped with instruments for study of the climatic parameters. The Environmental Survey Laboratory has modern chemical and radiometric instruments and a whole body monitor. The ESU is staffed with scientists trained in environmental measurement techniques, population studies and field experiments. The objectives of ESU are (i) to provide information for design on discharge limits (ii) to keep a record of air and water quality by monitoring (iii) to determine population exposure (iv) to recommend measures for remedial action, and, (v) assess the impact of releases on food, forage and water bodies and in general, on the utilization of the environment.

The nuclear power projects at Tarapur and Kalpakkam are close to the sea. The sea apparently presents an attractive proposition for the discharge of liquid effluents. Even knowledgeable persons recommend a coastal site for industries. 'It is a blessing to locate such a factory (fertiliser factory) near the sea. This applies to other industries also; but unfortunately often for political reasons industries are located on the most impossible sites requiring lakhs to be spent afterwards for waste treatment' (*COST Transactions, BARC 1970*).

It is unquestionably good advice against siting large pollutive industries near fresh water sources in this country where every effort should be made to conserve water supplies and their quality. *What is not popularly known is that even the sea is not limitless in its capacity to receive pollutants and dilute and disperse them beyond recognition.* The pollutants discharged to sea get concentrated in silt, sediment, plankton and fish and reappear on the beaches and in human diet. Even some of the degradation products from land wastes have been reported in mid-ocean fish. (*COST Transactions*).

The environmental studies at Tarapur indicate that tidal oscillations and silt load in sea waters are restrictive to waste discharges. Silt picks up radionuclides which can result in the contamination of beaches, fishing gear, and fish left for drying in the sun. Mass movement of effluents, flooding of low lying grounds by high tides, use of high tide waters for salt production, creek fishing etc. are factors against coastal discharges. Sea sprays can carry pollutants inland.

Tracer experiments in the lake at the Rajasthan Power Plant site show restrictive patterns typical of lakes namely, slow currents and stagnancy. Lake water movements are wind-dependent and unpredictable. The Rajasthan lake is built on the course of the Chambal river and the waters are used for drinking and farming.

An authorisation for release to the environment can be made on the following basis : (i) a permissible discharge level in the effluents and (ii) a total limiting discharge. Permissible discharge concentration limits in effluents have been published by official bodies and are available. Where the environmental processes of reconcentration are likely to neutralise the effects of dilution and dispersion, by selective deposition and uptake, the limits for release of effluents require to be modified and controlled by an overall authorisation for discharge. The total daily permissible intake calculated from recommended permissible limits in air and water becomes a better guide than permissible limits alone. Pollutants can be received through milk and foodstuffs from air deposition. Where the exclusion area is 300 metres or more it will be essential to set up surveillance units for monitoring pollution and conducting field investigations for recommending a discharge authorisation. The key to limit environmental pollution lies in keeping the discharges well below the safe recipient capacity of the environment.

The study of water movement and dilution availability can be made with a simple technique : a tracer like Rhodamine, bottle floats, theodolites and a few sampling devices. Many field experiments were carried out at Tarapur and Rajasthan using fishing boats and throw-away bottle floats. For simulating discharge conditions it is ideal to use a small amount of waste obtained in the initial stages of production along with dye as a tracer for confirmation. *E. Coli* present in sewage effluents has been reported as a marker in some experiments. If the discharge line and outfall are not properly engineered considering seasonal changes, dilution availability of streams in summer will not be realised.

Derived Limits

MANY experimenters follow the ecological concentration processes along the food chains which peak in fish or oysters and then calculate the total reconcentration factor. For most applications it will be enough to examine critical food items of direct interest like fish tissue and salt, and cut down the expense on elaborate investigations. When contamination of sea food and beach sands is likely, it will also be necessary to find occupancy on the beach and what portion of the catch is likely to be eaten daily per capita in the different population groups. The methodology is simple and can be applied to any site and pollutant.

On a similar basis, a limit on stack releases is recommended on the basis of dispersion parameters and rate of deposition of the pollutant on land and pastures. The releases can also result in the direct exposure to population from a moving cloud and through food chains. (air-grass-cow-milk-children)

The utilisation of the environment, population habits, location of housing, and downstream users impose restrictions on unlimited supply of water even when releases are made at levels declared as permissible. A total discharge authorisation (air plus water) depends on the safe recipient capacity of the environment alone. For implementation, and control a derived affluent limit is declared on the basis of the authorised release.

Near 70% of heat produced in power production is discharged in stack gases and condenser effluents. The effect of rise in temperature in waters is to lower the dissolved oxygen content. If wastes containing organic matter are discharged into the water body which also receives the thermal effluents, the degradation of organic matter is accelerated resulting in a further depletion of dissolved oxygen. In fresh water the maximum dissolved oxygen content is 7.1 mg per litre at 35°C. If through thermal discharges the temperature rises to about 40°C, the dissolved oxygen content comes down to 6.6 mg/litre in that region. A value lower than 4.5 mg/litre is detrimental to fish life and leads to insanitary conditions in the atmosphere. When there was a massive appearance of dead fish in the waters at Haji Ali, Bombay, the dissolved oxygen content in close-by waters was reported to be zero. It was not known whether this was due to degradation caused by the dead fish or that low oxygen values were prevalent earlier because of the discharge of untreated sewage effluents. In countries where the ambient temperatures are generally low (less than 10°C) fish death can take place by thermal shock when fish are trapped in the sudden efflux of thermal effluents.

The stench associated with shoreline discharges is due to anaerobic decomposition and release of H_2S. The combined effects due to heat and organic matter are more aggravating or synergistic in effect than when thermal pollutants are discharged singly. The water bodies always contain enough organic matter for such interactions. As a rule discharge of hot effluents directly to a water body should be avoided and specially when streams containing organic pollutants are also discharged simultaneously. Discharge of condenser coolant waters which are about 8°C above the ambient are made at Tarapur through a diversionary canal on land about 1,000 metre long before the waters join the sea. With this diversion, the increase in the temperature of foreshore waters are not detected beyond a kilometer from station. The conditions of turbulent mixing and evaporative cooling will not be same in all sites. Each environment in the micro region has an individuality and character of its own with respect to plant and population. This has to be identified. Thermal discharges should be kept in view in designing outfalls at a power station.

It has been possible from preoperational investigations carried out by ESUs to predict what possibly would be the component of releases that will prove most 'critical' in the environment (*Preoperational search for baseline radioactivity, critical food and population groups at the Tarapur Atomic Power Station site — First IRPA Congress 1966, Rome*). After the operations are started, the weaknesses

of the design make their appearance. Careful surveillance for changes in base line levels of pollutants in the environment and objective assessments of exposure are necessary along with an expert knowledge of processes to suggest economic corrective measures. A modification of a process, layout and outfall, however expensive, should not be interpreted as a reflection on inept planning originally. On the contrary, planners and production engineers should be associated in such introspection and review.

In the back-fitting process it will be useful to consider utilisation of waste products and reuse of water. It may be surprising to find how profitable such studies can be in the long run.

India is not a very highly populated country if only population densities are compared. The growth of uncontrolled metropolitan cities and industries has caused widespread pollution in these areas. *The siting criteria is a good tool for control, provided residential areas are not allowed to crop up uncontrollably in the vicinity of industries and the industry itself is not expanded unduly on the site.* What is probably required is the right attitude to development, integrating production programmes with protection and conservation of the environment. It should not be difficult to achieve this goal with proper environmental strategies in India where the largest industries are controlled by the Government.

The rectification of water supply in metropolitan cities belongs to a different order. The magnitude of the problem of pollution by domestic wastes can be gauged from these examples.

At a recent symposium reviewing problems of an old city, it was pointed out that because the piping for drinking water and sewage drains were laid side by side some 25 years ago, leaks and short supply of drinking water have led to short circuiting of flowing sewage in drinking water supplies. The expenditure to replace the corroded pipes was estimated at Rs. 2,000 crores over a period of 20 years. A modification of this kind may be difficult to implement even if funds are made available.

One of the largest occurrences of waterborne infectious hepatitis epidemic was reported in Delhi (1955 — 56) where over 20,000 were hospitalised and ten times that were considered subclinical (*Waterborne Microbiology, John Wiley & Sons 1972*). Over 8,000 were reported to be dead.

The sources of pollution in an industrial process can be identified and corrected even after the plants are commissioned, with some loss of production time and profits. Such alternatives are not easily open for control of slums and sewage pollution of water in old cities because of congestion and lack of sanitation in rural areas for want of treated water supply and piped distribution. The need for proper planning and upkeep of residential areas and municipal services is as pressing as that of siting the industry and operating it safely. ●

Hyderabad.

Developing on Our Own

INDIA after twenty-five years of political freedom is a mixture of achievements that are gratifying and, at the same time, failures that are difficult to understand. There has been visible industrial progress. Other kinds of progress are signified by favourable changes in the various statistical indicators such as life expectancy, the percentage of literacy, the millions of births prevented etc. But even though production may have increased greatly in course of time, perhaps because of inadequate distribution, the rise in living standards for a large number of people has not been significant enough. Because we have not managed well enough to channel the flow of increased production to the section of people who are not very well off, there has been no substantial improvement in the quality of life for most people. The incongruities are not only indicative of our potential to work for improvement but also, at the same time, of our inability to plan, marshall and manage.

There is hardly any question about the utility of industrial technology for our development. Ours is a large population and to assure all of it a reasonable quality of life, we have to produce for massive consumption. Such a large volume of production will entail adequate application of industrial technology; even though we may be inclined to question acquisition of technology as an end, we cannot question its utility as a means. It is important, therefore, that we consider all measures for rapidly extending and strengthening our technology.

The moment the topic of technology comes up for consideration, a lot of people, people of influence and power, start making a case for import of foreign technology. Arguments are adduced as to how it takes a long time to develop India's own technology and how this delay is intolerable because it will keep us always behind the advanced countries. Eventually, the conclusion is offered that therefore we should use the helping hand of foreign technology. Then, after a policy is evolved in this way, we lose sight of the original premises on which the arguments for such a policy were based: no purposeful efforts are made to ensure that such foreign help, purchased at high price, accelerates the process of our catching up technologically.

It is not difficult to see that the pace of our industrial development has been disproportionately slow considering the huge outlay we have so far made on import of technology. Technology does not take root without a proper innovative base of a nation's own. Instead of allowing the highest priority to the rapid development of such a base we handicap indigenous innovation unfairly against foreign technology. Indigenous technology is decried as obsolescent and attempts are made to sap its strength.

Debilitating Foreign Deals

YET there are compelling reasons for adopting a development strategy based on indigenous technology. One of them has to do with the suitability to Indian conditions of the technology we must use. If we were to import technology, it usually tends to be high in automation calling for a minimum of personnel to run the automatic plant and machinery. A major part of such personnel have to work on maintaining the plant constantly in the best running condition, drawing large wages in view of the technical complexity of their job and the heaviness of their responsibility. Unfortunately such a situation is inconsistent with the prevailing urgency to provide widespread employment to the maximum number of people. As we observe in many of our high-capital industries, the equipment tends to be down for an uneconomically large proportion of the time. In spite of the smallness of the number of people required to run such plants, we do end up under pressure of local conditions employing a larger number than necessary. In the process, the emphasis on maintenance responsibility becomes diffused and mostly lost. Aggravating this already bad situation is the fact that in many of our foreign deals, an excess of expensive plant and machinery is dumped wastefully on us, the collaborators and consultants maximising their offtake by being lavish with our money. The end result is expensive production. There is no point in blaming the current circumstances for such a state of affairs. We have to realise that we are not ready for heavily automated industries. If we adopt an indigenous approach we shall concentrate first on labour-intensive technologies. Later as we develop sufficiently and reach a state of

Third generation computer developed by the Electronics Corporation of India Ltd., Hyderabad.

full employment, when we feel a genuine shortage of labour, we shall be able to introduce the necessary degree of automation. Our immediate goal will be to develop simple mechanical aids to the limited extent of removing drudgery from labour.

Another reason has to do with the costs we pay. It is obvious that in any import of technology, we have to pay a cost covering R & D expenditure that goes into developing of that technology in the exporting country. Where there is need to minimise our outlay, are we justified in incurring such costs ? On the other hand, by adopting an indigenous R & D policy, we shall be giving opportunities to our own people to work and gather valuable experience that will benefit our own country.

Costly Dualism

MANY of the development goals that we want to achieve through planning, national direction, control, monitoring, surveying and follow-up processes already bristle with problems of time, money, motivation and inducement. Instead of tackling them with a firm stand, we add to them through a two-headed approach involving participation of foreign technology (which is difficult to control), and the generation of indigenous technology. This dualism has already cost the country heavily in that indigenous efforts have received little backing in practice, people taking the easy "foreign" way out, closing their eyes to the expense involved and not realising how funds are vitally needed for the growth of indigenous innovation. For more than twenty-five years we have given foreign technology a free play in the country. It has not proved to be the boon for development that its protagonists had portrayed it to be; it never could be a boon, since it was all along only a way to further the commercial interests of the selling nations. But even more significant is the objection that foreign knowhow has evolved in environment different from ours and is not generally suited to our needs. Contrary to the protestations of the protagonists of foreign technology, the development gap and the technology gap have grown wider over this period and will continue to grow ever wider if we do not forthwith severe our dependence on it. The time has now come for the nation to give up this frustrating course and to chart its own self-reliant course. The time has now come for taking the bold, unambiguous step of banning the import of all foreign technology. It should be our policy hereafter to base our development entirely on indigenous efforts.

The Approach

IS IT possible for us to be self-reliant in technology ? This question is on the minds of too many people and it is this doubt that has come in the way of the growth of indigenous technology. It is a reflection of the awe we have for things technical and the lack of confidence stemming from lack of knowledge. This awe and this lack of self-confidence also are the reasons behind the fascination we have for foreign technology and the innocent reliance we place in it. All we need to do is change our attitude towards the Indian science worker. He is capable of delivering goods if he is allowed to. There has been in recent years adequate demonstration of this fact.

To ensure success in the operation of the indigenous policy, we have to adopt a series of simple measures all of which emphasise the indigenous theme. The first is the planning of targets. It is better, when trying to work our targets, first to look at the needs as they are, rather than allow our planning to be bogged down even at the outset in a mental struggle trying to balance severe resource limitations against innumerable urgent needs. To be specific we should fix a goal for GNP achievement that will reflect our needs. I would say something like Rs. 250,000 crores, assuming that we can keep our population reasonably stationary in the meantime. It is only then that we should look at resource

limitations. No doubt there may be limitations; they may even be severe. We can, however, get around such problems if we allow reasonable time targets. Invariably, the setting up of meaningful goals can lead to the discovery of the means to achieve them. But if our goals are not meaningful and they are set small, we slacken our efforts to achieve just these and often fail from lack of enthusiasm.

Let me illustrate a little further with the example of electronics. When we reach the state of "reasonable quality of life", our electronics production will be in excess of Rs. 5000 crores. This figure is a conservative estimate, and as we progress beyond the level of "reasonable quality of life",

Commercial TV sets on the assembly line of ECIL, Hyderabad.

it will rise rapidly. In other words, the development gap immediately facing us, projected to the electronics plane, is above Rs. 5000 crores considering that today our total annual electronics production is a negligible Rs. 200 crores. It is this Rs. 5000 crores gap that we must attempt to bridge in the shortest time possible, and not what we see today as the difference between our scaled down needs and indigenous production which is very much smaller. We have defined, however crudely, one dimension of the problem, one pertaining to development in electronics. The overall national development problem can, in this manner, be defined *in toto* in a dimension-by-dimension approach; in a similar way its solution can also be attempted.

It is obvious that this kind of exercise has to be indigenous. The means we develop to achieve our goals will be suited to the country's needs and culture and will take full account of all our limitations till such time as progress obliterates them. What if we are a little "obsolescent" in our techniques ? As long as we ensure that there is no gap between our ability and our needs, there will be no "obsolescense" which will really affect progress.

The National Attitude

THERE are some deficiencies we have to recognise in the Indian system today and which we must sincerely attempt to remove. There are lacunae that weaken management, commitment and discipline. These come in the way of hard organisational work which is very important for the success of national development. I think they will disappear once sincere, well-concerted action begins and all understand the meaning of their action, as will happen if we can establish teamwork on a national scale to achieve worthwhile national objectives. Then there are things like education control where we must recognise a time-priority for skills needed and attempt to guide the educated manpower output to match these, in quality and the right quantity. There should at no time be expensive attempts to inculcate skills for which we have no major use immediately and which will therefore only rust without meaningful employment. This is today the crux of our manpower problem: need and availability not matching and each languishing to the detriment of the nation.

We must work to eliminate these and other deficiencies quickly. These are not really serious problems of resources and hence can be readily solved if we are determined. If we resort to a policy of self-reliant indigenous development all round, it can have the effect of toning up the sagging national confidence and bringing about the necessary sense of urgency, leading to the creation of a healthy, purposeful national attitude. ●

Director, Physics Group,
Bhabha Atomic Research Centre, Trombay

The Promise of Fast Breeder Reactors

"NO power is as costly as no-power." The often quoted adage that Dr. Homi Bhabha preached over a decade ago has come true as evident from the experience of the past few months. There is today a greater awareness of the need to properly plan for adequate power for the future. In the years to come nuclear power will be called upon to play an increasingly larger role. The vital question is : how much, and what type of reactor will meet the need ?

All the commercial nuclear power stations operating in the world at present have thermal reactors. Like any conventional power station, these N-Power Stations consist of a heat source, steam boiler and turbo-generator. In a nuclear station, the heat source is the nuclear reactor. Here energy is produced by the fissioning of uranium atoms caused by neutrons. Since neutrons are themselves produced in the fission process, a neutron chain reaction sustains a continuous series of uranium fissions. The term 'criticality' means that optimum conditions have been established for fission to be maintained at a steady rate. These conditions depend on the actual distribution of fuel material, heat removing fluid, moderator etc. and forms the subject of 'Reactor Physics."

Limited by the small percentage ($< 1\%$) of readily fissionable U^{235} present in natural uranium, earlier attempts were restricted to making critical configurations using the property that neutrons with small energies have greater probability of causing fission. A moderator was therefore introduced to slow down the fast neutrons produced in fission. Heavy water and graphite are better moderators enabling thermal reactors to be built with natural uranium while moderation with ordinary water, which is more neutron absorbing, requires slightly enriched uranium. Thus the Tarapur reactors are moderated by ordinary water and use enriched uranium whereas the Rajasthan reactors use heavy water and natural uranium.

Thermal reactors have one inherent drawback: they can "burn" only a very limited fraction ($2 \sim 3\%$) of the total uranium available in nature. This is due to the small percentage of U^{235} in natural uranium and the relatively small amount of plutonium that is produced in thermal reactors.

If the bulky moderator is eliminated and conditions are so arranged that a fission chain reaction is established by means of fast neutrons alone, one gets a "fast reactor." The main advantage of this type of reactor is the great improvement in neutron economy. Wasteful absorption of neutrons in fissile, structural, control and other materials is minimised. Thus 1 kg. of plutonium produces 50% more energy in a fast reactor before being "used up" than in a thermal reactor. Fast reactors have the unique property that they can breed or produce more nuclear fuel than they consume, while continuously generating power at full capacity.

Physics of Fast Reactors

THE fissile fuel inventory in a fast reactor is larger than in thermal reactors but the physical size of the core is much smaller because of the absence of a moderator. While the principle of the fast reactor has been known from the very beginning of the atomic age (in an atomic bomb the neutron chain reaction is maintained by fast neutrons), it is the small size of the core with resultant high power densities that has postponed technological exploitation of the potentialities of the fast reactor. The power density in the core of a typical large fast breeder power reactor would be 400 kw/litre, which is several times that in thermal reactors. Conventional coolants such as water are just not efficient enough to take away the enormous quantities of energy released in the small fast reactor core. Besides, the coolant has to be such that it will not slow down the high speed neutrons nor absorb them in a wasteful manner. Only liquid sodium is found to fulfill the requirements of a practical and effective coolant for fast reactors. It has indeed proved to be a very efficient and economical coolant. Sodium has very good thermal conductivity and

low moderating properties. It has a high boiling point and does not require high pressures thus making the piping, pumps and reactor vessel design less complicated.

For fuelling nuclear reactors there are three basic fissile isotopes available. These are U^{235}, Pu^{239} and U^{233}. Of these only U^{235} is found in nature; the other two, namely Pu^{239} and U^{233} are man-made isotopes. In fact plutonium is an altogether new man-made element. It is obtained when U^{238}, which is the more abundant ($> 99\%$) of the isotopes found in natural uranium, absorbs a neutron and becomes Pu^{239} through an intermediate radioactive decay step. Thus, U^{238} which is not fissionable by low energy neutrons, gets transmuted to easily fissionable Pu^{239}. This reaction plays a central role in the nuclear energy business. For this reason U^{238} is referred to as a fertile material. Thorium is another fertile material plentifully available in nature. On absorption of a neutron, Th^{232} eventually becomes U^{233} which is also a good fissile material for nuclear power generation. These two reactions are important because they provide a means of converting the otherwise useless but plentiful supplies of U^{238} and Th^{232} in nature into valuable fissionable nuclear fuel.

The Th^{232}—U^{233} cycle has particular significance for us since India has vast resources ($>$ 600,000 tons) of thorium but only limited supplies of uranium ($\sim$ 30,000 tons). If we are to plan a long term nuclear power programme for the late eightees and early ninetees the potentialities of the Th^{232} — U^{233} cycle has to be fully considered.

The operation of a nuclear reactor, whether of the thermal or fast neutron type requires only that we assemble a 'critical mass' of fissile material. The principle of the reactor itself does not require that fertile isotopes such as U^{238} or Th^{232} be present in the reactor. But if we were to fuel it with a mixture of fissile and fertile isotopes, then in the course of reactor operation, part of the fertile isotopes would be converted into fissile nucleii due to neutron absorption, the U^{238} yielding Pu^{239} and Th^{232} being ultimately converted into U^{233}.

The incentive for using a mixture of fissile and fertile isotopes is two-fold : (a) Firstly, the life of the fuel in the reactor is increased. This is a short term objective. As the fissile isotope gets 'burnt,' fresh fissile material would be generated within the reactor itself, compensating to some extent the loss of the original fissile material (b) The long term objective is that the fertile isotopes U^{238} and Th^{232} get converted into Pu^{239} and U^{233} which can then be used to fuel new nuclear stations to generate more power.

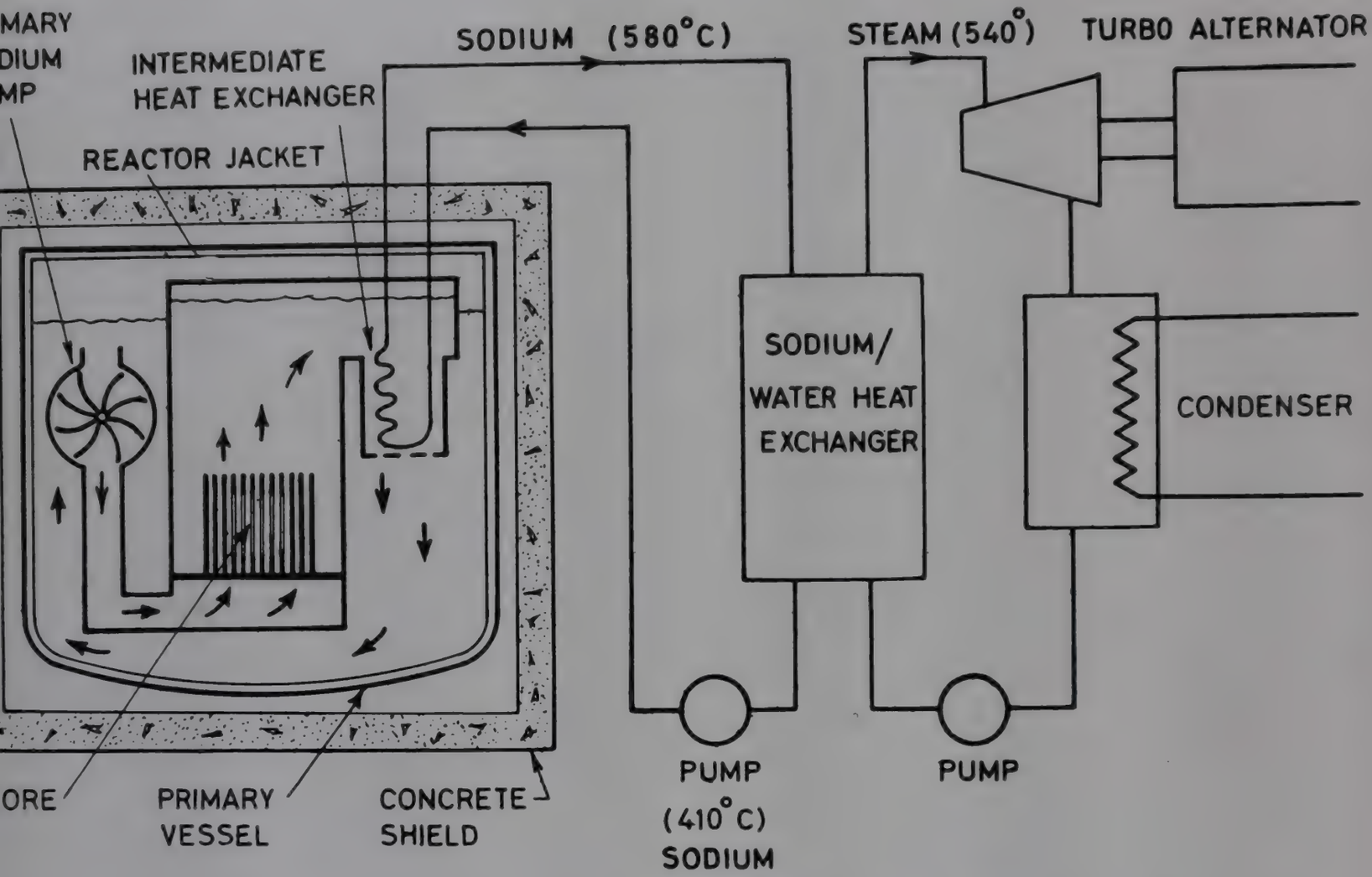
If one were to look at the overall consumption pattern and flow of fuel in a breeder reactor system whose breeding ratio is greater than unity, it would appear as if the fast reactor actually 'burns' the abundantly available fertile isotopes while the fissile inventory constituting the basic critical mass of the reactor only acts as a kind of 'catalyst' and that too a special type of 'catalyst' that produces more of itself for use in other reactors ! Herein lies the promise of fast breeder reactors.

The Engineering Problems

THE technological challenge is to keep the breeding gain high enough to obtain short fuel doubling times. In other words the time required for one breeder reactor to produce sufficient extra fuel for starting a second breeder reactor should be low. With current concepts, doubling times achieveable appear to be in the range of 15 to 25 years.

What are the engineering problems that have to be faced in designing and operating fast reactors that would both generate power as well as breed new fissile material ? It was mentioned earlier that sodium is the almost unanimous choice for extracting the heat produced in the core. But sodium has never been used on any significant scale by industry before the advent of fast reactors. Sodium is a metal and is solid at room temperature. Sodium gets intensely radioactive while passing through the reactor core. Usually the hot sodium is circulated through the core in one or more primary circuits. The primary sodium passes the heat on to a secondary sodium circuit in a heat exchanger. The secondary sodium then transfers the heat to a final water circuit which raises steam for driving a turbine. Fig. 1 is a schematic representation of a fast breeder power reactor. Sodium has great affinity for oxygen and water. There would be several tonnes of sodium in the reactor vessel and associated piping, and all this has to be kept chemically very pure, especially oxygen-free. Even very small quantities of dissolved oxygen, of the order of a few parts per million, are found to cause severe corrosion problems.

One of the major fears in nuclear reactor operation is the possibility that coolant flow through any fuel subassembly or section of the core would decrease or stop



SCHEMATIC DIAGRAM OF SODIUM-COOLED FAST BREEDER POWER REACTOR

altogether, for some reason. If this happens the fuel elements will over-heat and, in the worst case, melt. In a fast breeder reactor sodium flows between fuel pins through gaps less than a millimetre in size. It is therefore necessary to ensure that small extraneous objects do not enter the circuit and block coolant flow in any region of the core. Sophisticated instrumentation has to be devised to sense if the sodium has started boiling in local pockets of the core or if the fuel pins are getting over-heated.

The design of the secondary heat exchanger where sodium flows on one side and water on the other is a particularly intricate job, considering the violent nature of the sodium-water reaction.

Apart from the above more or less conventional problems, the fast reactor designer has to face an altogether new problem peculiar to nuclear technology. This is the 'damaging' effect of fast neutrons on the structural materials and fuel elements. The neutron flux in the core of a fast breeder reactor may be 4×10^{15} n/cm^2/sec. At these high flux levels each atom of the stainless steel cladding of the fuel will be hit once a day by a fast neutron or a recoil nucleus. This severe knocking completely upsets the basic ordered structure of fabricated components. Similarly a problem at the forefront of fast breeder development is the swelling of stainless steel when subjected to intense fast neutron fields. How much power can one extract from a given core before the reactor needs refuelling ? The answer to some of these questions will

directly affect the economics of power generated by fast reactors.

Efficiency of Fast Reactors

INSPITE of the numerous engineering problems that exist, today the fast breeder reactor is no more a 'physicists pipe dream.' It is well past the pilot plant stage and is heading in the direction of becoming a commercial, economically competitive reality. About half a dozen experimental sodium cooled fast reactors producing power in the range of 5 MW to 60 MW have been in operation in the technologically advanced countries for several years now. The USSR has recently commissioned a 250 MW(e) prototype fast breeder and by the end of this year two more such second generation prototype units would become operational in the U.K. and France respectively. U.S.A., Germany and Japan also have ambitious breeder reactor plans.

Sodium cooled fast reactors possess several other attractive features as well. The cost of power generated by them is so insensitive to the cost of uranium or thorium mined that it has been estimated that even very low grade ores can be economically mined and used. The efficiency of these reactors in converting heat energy into electric power is $> 40\%$ compared to the $< 30\%$ of thermal reactors. This has a very favourable effect on the amount of waste heat rejected to the environment.

In order not to be left behind in this exciting development, and keeping in view the long term potentiality in the Indian context, the Atomic Energy Commission has set up a Reactor Research Centre (RRC) at Kalpakkam near Madras mainly to develop breeder reactor technology. The development of the Fast Breeder Reactor requires the coordinated effort of scientists and engineers of several diverse disciplines ranging from physics and electronics to metallurgy and mechanical engineering.

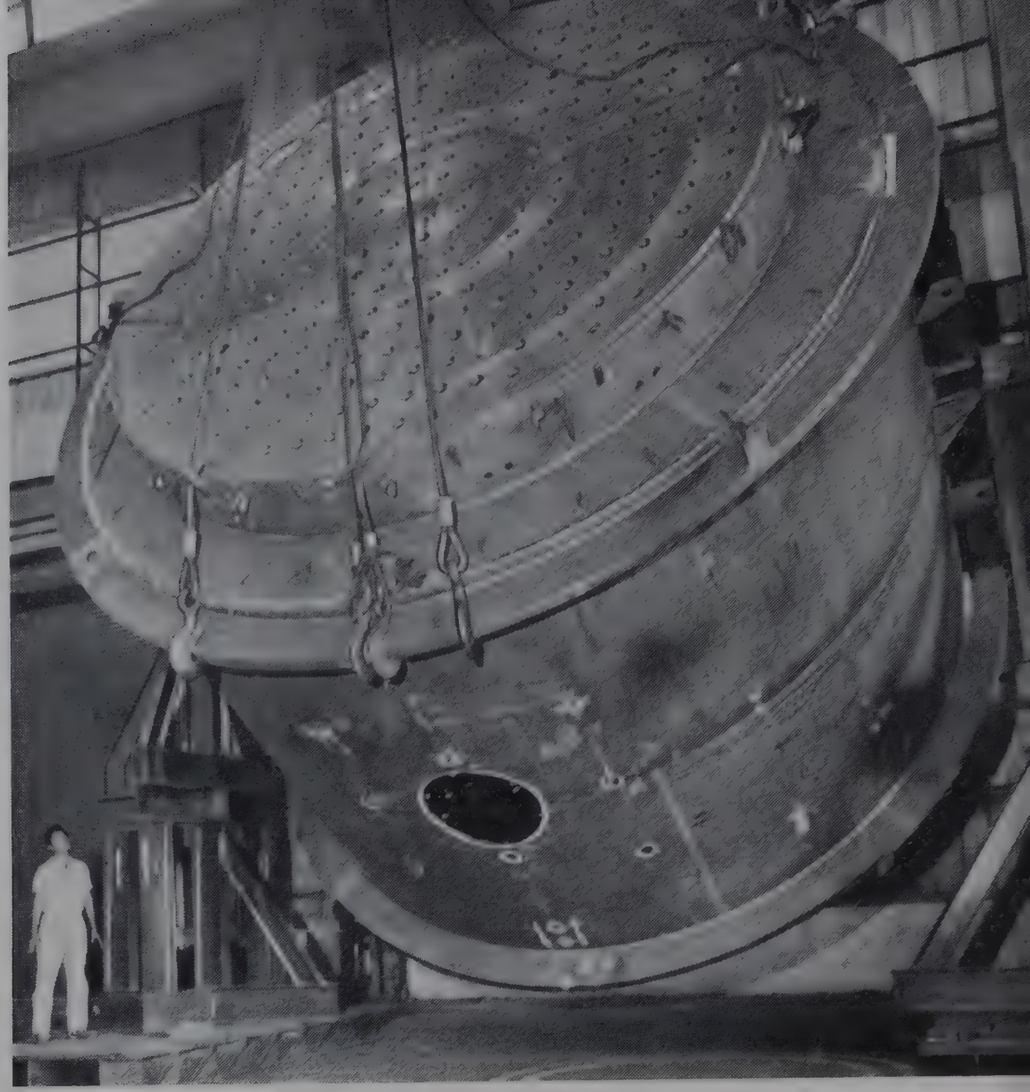
The main experimental facility at RRC would be a 40 MW (th) sodium cooled Fast Breeder Test Reactor (FBTR), which is being constructed in collaboration with the French Atomic Energy Commission. This reactor would be similar to the highly successful French reactor 'RAPSODIE' in operation at Cadarache since 1967. FBTR at Kalpakkam is scheduled for commissioning in 1976. It will have a thorium blanket in which U^{233} would be bred providing an opportunity for obtaining first hand experience with the relatively undeveloped Th^{232} — U^{233} fuels.

Meanwhile, at the Bhabha Atomic Research Centre in Trombay, the country's first experimental fast reactor was commissioned in May 1972. The plutonium fuelled zero energy experimental reactor, PURNIMA, was designed and constructed entirely by the scientists and engineers of BARC. The reactor uses about 20 kg of plutonium. On account of its high radioactivity and toxicity, the chemical separation of plutonium and its fabrication into fuel pins clad in stainless steel tubes had to be done remotely in completely sealed cells or 'glove boxes.' The design of the control system of PURNIMA posed several challenging problems. PURNIMA represents a small but significant step in our efforts towards the breeder reactors of the future.

An aspect not specifically touched upon in this article is the question of safety. Some people have expressed fear that plutonium which is indeed a highly hazardous substance could escape and contaminate the environment in the event of an accident. It is to allay such fears that all reactors are provided with suitable barriers in the form of containment structures which would not permit dangerous radioactive materials to escape even in the highly unlikely event of a serious accident. Depending on the degree of optimism, fast reactors have been described both as the "salvation of mankind" and "the greatest mistake of man". But those who want us to believe in the latter are also people who call the automobile and the internal combustion engine as a great folly, polluting as it were the atmosphere and the very air we breathe. But one thing does seem sure, that thanks to the 'environmentalists' the standard of safety expected of reactors, both fast and thermal, along with conventional chemical plants and automobiles, is going to become higher in future, and this is something that can only be welcomed. ●

Dr. M. R. Srinivasan
Deputy Director,
Power Projects Engineering Division,
Dept. of Atomic Energy.

Towards Self-Reliance In Nuclear Power

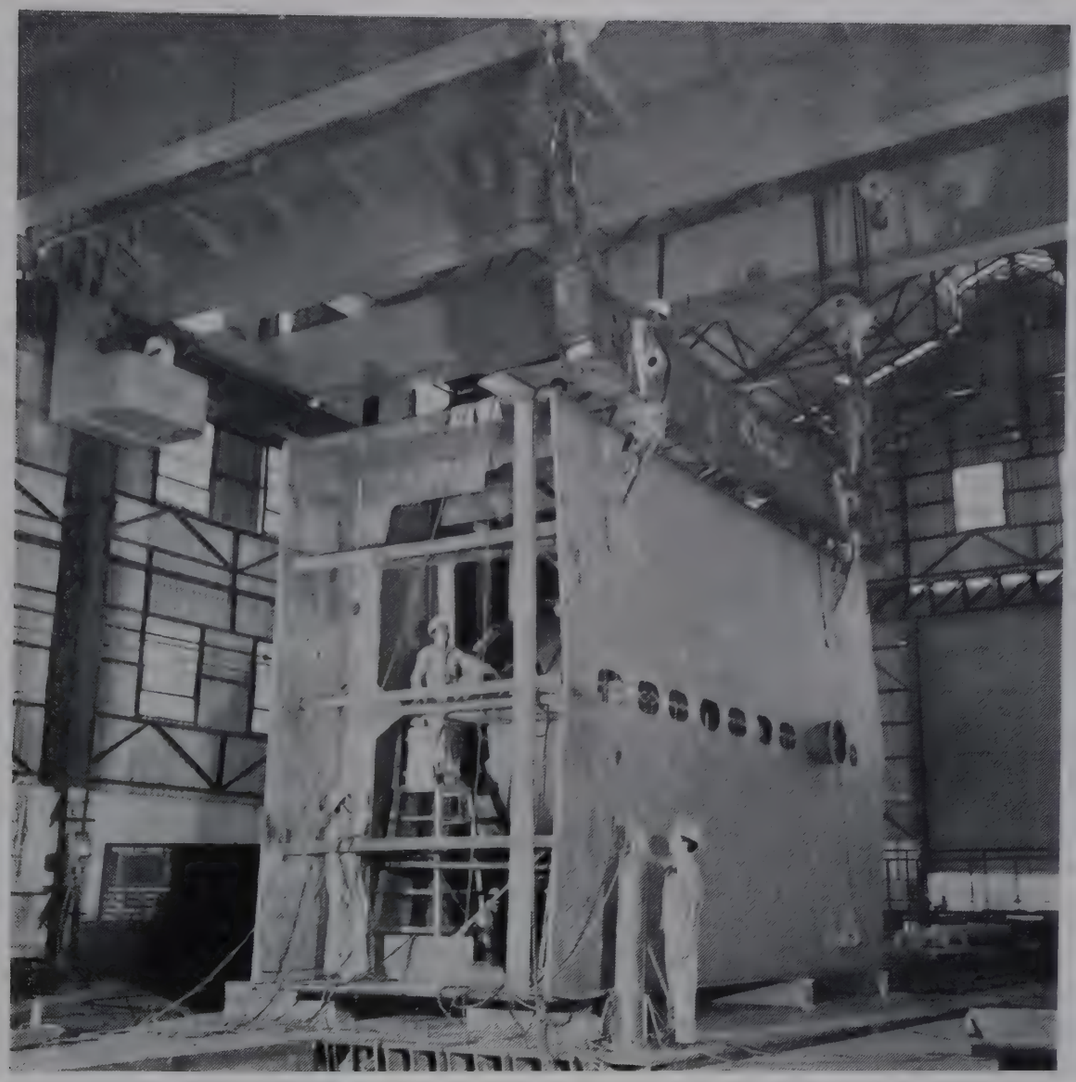


The Calandria — the reactor vessel for Unit II of the Rajasthan Atomic Power Station which has been made by Larsen and Toubro in Bombay.

THE basic philosophy of the nuclear power programme as envisaged by Dr. Bhabha is a step-by-step approach towards self-reliance. This is clearly seen in the transition from Tarapur to Rajasthan and on to Kalpakkam. In the case of the Tarapur Atomic Power Station, a turn-key type contract was entered into with the General Electric Company of the U.S.A. for the design, construction and commissioning of the Station. Engineers of the Department of Atomic Energy were however responsible for site selection, preparation of tender specifications, formulation of the contract, review of designs and inspection activities both at site and at the manufacturers' works.

A different type of arrangement was entered into for the Rajasthan Atomic Power Station. In this case, Atomic Energy of Canada Ltd., furnished the designs on the nuclear side while Montreal Engineering Company, a Canadian firm of consulting engineers, provided the designs and engineering assistance for the conventional areas of work. The responsibility for the execution of the Project was, however, retained by the Department of Atomic Energy. With the experience gained in the first two atomic power stations, the Department decided to embark on the third station at Kalpakkam as a totally Indian effort. The Department has assumed full responsibility for design, engineering and execution of this Project. It has, however, associated established Indian consulting engineering firms to render assistance in various conventional parts of the work.

For the Tarapur Station, practically all the equipment — both nuclear and conventional — came from the U.S.A. For the Rajasthan Station, right from the inception of the Project, efforts were made to locate possible Indian suppliers. This effort not only extended to conventional items of equipment but also to the nuclear ones; the major conventional items which came from Indian suppliers for Rajasthan Station Unit-I include the main generator transformer supplied by M/s. Heavy Electricals (India) Limited, Bhopal. This 250 MVA generator transformer was the largest transformer then manufactured in the country. Because of the inadequate capacity of the manufacturing industry at that time, it was necessary to import all the major nuclear equipment such as the Calandria, Dump Tank, Primary Heat Transport Pumps, Fuelling Machines,



The Dump Tank for the Rajasthan Atomic Power Station Unit-II under fabrication.

Steam Generators, etc. Even on the conventional side, the turbine generator, circulating water pumps for condenser cooling, travelling water screens and other equipment had to be imported as they were outside the range of manufacture in the country. However, certain items were taken up for manufacture in the Central Workshops of the Bhabha Atomic Research Centre. These included thermal shield plates, fuelling machine vault doors etc. Indian industry also put in considerable efforts to accept the challenge of heavy precision fabrication work; for instance Heavy Electricals (India) Ltd., Bhopal took up finish fabrication of the end-shield assembly under the supervision of the Canadian manufacturer. The end shields are massive components weighing approximately 120 tonnes. Fabrication of these components not only involves welding of heavy plates with minimum distortion but also requires special heat treatment and machining to close tolerances.

A concerted effort to get major nuclear components fabricated in India was initiated for the second unit of the Rajasthan Atomic Power Station. In some instances technical know-how agreements were entered into with the Canadian suppliers of equipment for the first unit for passing on the know-how required for fabricating similar equipment in India for the second unit. For example, the steam generators of RAPP-II were fabricated by an Indian firm M/s. Larsen & Toubro under such an agreement. Fabrication of the steam generators calls for special welding techniques like overlay welding, tube-to-tube sheet welding

with minimum ligament spacing, and welding of monel material. The standard of fabrication has to be of the highest kind as heavy water is the primary fluid, and no leakage is permitted of this valuable material. The last of the eight steam generators required for the Rajasthan second unit were delivered by the manufacturers in March 1972.

Major Efforts at Indigenisation

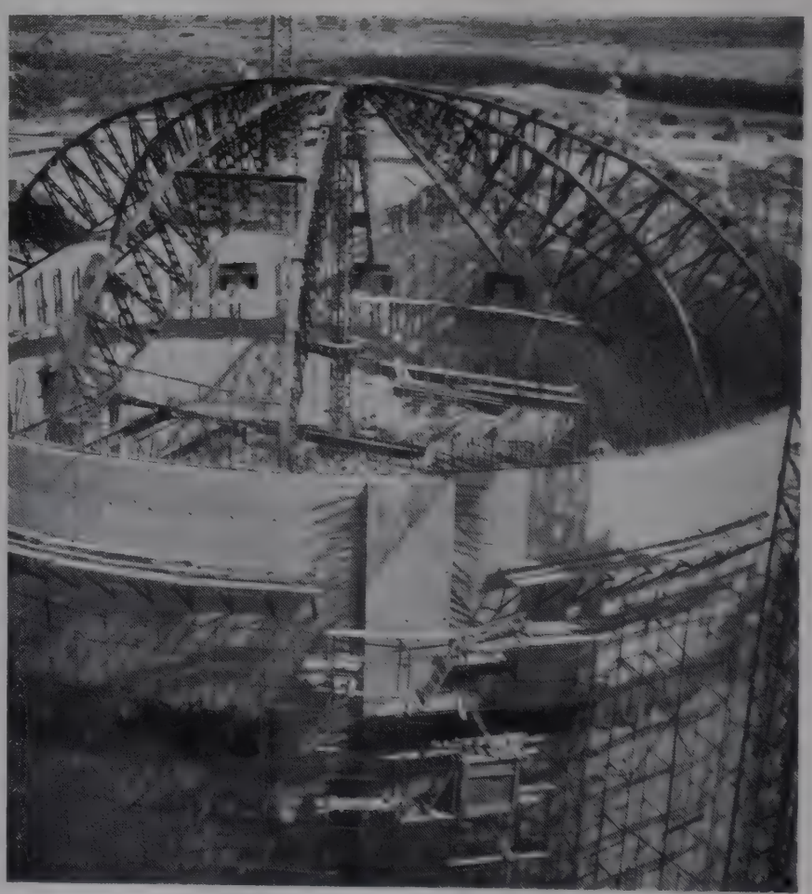
THE experience gained in finish fabrication of end shields of Unit-I at Heavy Electricals (India) Ltd., Bhopal was taken advantage of to manufacture in India end shields of Unit-II. End shield fabrication involves a number of difficult operations such as machining of semi-circular steel slabs of about 12" thickness, trepanning of 306 lattice positions, shrink fitting of slab assemblies in the shell assembly, welding of lattice tubes to tube sheets by submerged arc welding, stress relieving of the complete assembly, and finish machining of the assembly to close tolerances. The end shields for Unit II of the Rajasthan Station were completed by December 1972. The Calandria for RAPP-2 was fabricated by an Indian firm *viz.* M/s. Larsen & Toubro. The Calandria consists of a cylindrical shell about six metres in diameter and about five metres in length with a rectangular dump port assembly at the bottom of the cylindrical shell. The dump port assembly is a complex fabrication and requires a prototype assembly to be fabricated in the first instance to arrive at the sequence of fabrication and welding procedures so that the required tolerances can be achieved on the finished component. A major problem in the fabrication of the Calandria has been that of controlling the distortions in large weldments.

Another large component involving precision welding of stainless steel is the dump tank. This component for RAPP Unit-II has been fabricated at Walchandnagar Industries and has just been delivered to site.

A major effort at indigenisation has gone into the fabrication of fuelling machines for Rajasthan Unit-II and the Madras Atomic Power Project. The fuelling machines are located in the fuelling machine vaults which are normally inaccessible during reactor operation. They are employed for fuelling the reactor while on power. Most of the operations of the machine head and fuel handling are carried out using hydraulic rams and cylinders. Since the fuelling machine is filled with heavy water at about the same temperature and pressure as in the reactor, special design features are employed to restrict leakage to a negligible extent. Most of the components in the fuelling machine are fabricated from precipitation hardening stainless steel and special surface treatments are adopted to reduce wear in service. The Central Workshops of the Bhabha Atomic Research Centre have been entrusted with much of the precision machining required for the fuelling machines. A number of precision components such as shielding plugs and sealing plugs are being supplied by Indian industry. These components also call for precision machining and special heat treatment procedures.

The scope of indigenisation in the conventional equipment for RAPP-II was however limited by the manufacturing capability available with Indian manufacturers. It was possible to entrust to Indian industry fabrication

View of the reactor building of Unit I of the Madras Atomic Power Station showing centering framework for the prestressed concrete dome.



The first steam generator of Unit I of the Madras Atomic Power Station being unloaded from the ship at Madras.

of equipment such as process water pumps, circulating water pumps, condenser, feed heaters and switchgear. However, major equipment like turbo-generator had to be imported as this was still outside the range of Indian manufacture at that time.

It would be appropriate to mention some features of civil construction at the Rajasthan Station where techniques more suitable to Indian conditions were adopted. For example, the reactor building of the first unit of the Rajasthan station has a prestressed concrete dome in place of a steel dome which is used for the Douglas Point reactor building. For the second unit of the Station, this kind of substitution went a step further with the dousing tank also being constructed in prestressed concrete.

In the case of the Madras Atomic Power Project, major efforts are being made to achieve a high degree of self-reliance. Full advantage has been taken of the expertise generated within the country for fabricating major nuclear components for RAPP-II by placing repeat orders wherever feasible. Special efforts are being made to produce in India the controlled leakage pumps required for pumping the heavy water of the primary heat transport system. Notable progress has been made in the conventional field wherein the turbo-generator is being fabricated in Indian shops. The turbine is being made by M/s. Heavy Electricals (India) Limited to a design obtained from AEI-English Electric Company of U.K.; the generator is being manufactured by M/s. Bharat Heavy Electricals Limited, Hardwar based on a Russian design. Other major items which are being manufactured in India include feed water heaters, travelling water screens, condenser, sea water pumps for condenser cooling, stand-by emergency diesel generator sets, etc. It is expected that the foreign exchange content for the Madras reactors will be only about 20%, confined primarily to import of raw materials like stainless steel, alloy steel, heavy plates and structural elements, monel and such other materials which are not yet within the scope of supply of Indian manufacturers.

Special Features of MAPP

A NOTEWORTHY feature of the Madras Atomic Power Station is the adoption of a number of changes in the design, notably in the containment system. Thus, for the Madras reactors, the reactor building is being constructed in prestressed concrete. In addition, a double containment principle is being adopted whereby the prestressed concrete reactor building has a second envelope of rubble masonary wall with an annular air gap. With this arrangement, release of radioactive material to the environment even under accident conditions can be reduced considerably. In addition, the containment adopts the vapour suppression concept whereby the maximum pressure within the reactor building under accident conditions is kept low. The MAPP reactors have also been designed for a slightly higher output; each reactor has a gross capacity of 235 MWe with a net capacity of about 215 MWe. Arising from the special conditions of the site, sea water for condenser cooling purposes will be drawn by an intake structure located about 400 metres from the shore and drawn into the forebay of the pump house through an undersea tunnel. This is the first example of

such a construction being adopted in the country and is expected to overcome the problem of sand bars which has affected some of the thermal power stations located on the eastern sea board of the country. In the evolution of the designs of the cooling water system at Kalpakkam, considerable model testing has been carried out at the Central Water & Power Research Station at Khadakvasla to finalise the shape, location and the size of the intake system. Similarly, the design of the outfall structure has been evolved to minimise the risk of recirculation of the warm discharge water towards the intake. In the case of the reactor containment building also, structural model tests are currently being carried out at the Structural Engineering Research Centre, Madras to confirm the theoretical analysis used for design purposes.

While in the case of the Madras Atomic Power Station a number of design modifications have been made, the basic reactor design has remained substantially the same as at RAPS. For the Narora Atomic Power Project, on which design work has been undertaken, it is proposed to introduce a number of improvements and simplifications. For example it is proposed to adopt an integral calandria end-shield and shield tank concept, whereby the complicated vault construction including precision matched thermal shield plates and lining of the vault wall could be eliminated. It is also proposed to reduce the number of steam raising units by using larger size components. Similarly it is proposed to reduce the number of primary heat transport pumps from eight to four. The entire structural and support systems are to be re-designed keeping in mind the siesmic characteristic of the site. The end-shields for the Narora Project will employ a modification whereby the heavy steel slabs in the shell could be replaced by steel balls, thus reducing the transport weight of the component substantially. In the design evolution of the Narora reactors, we are keeping in mind the possible designs for future 500 MW reactors. It is also proposed to use basically the same components as would be required for the larger reactors, which could adopt twice the number used for the Narora reactors. Thus we may use for Narora four boilers and four primary heat transport pumps and, for the 500 MW reactor, eight boilers and eight primary heat transport pumps of approximately the same size as for Narora.

The Department of Atomic Energy is in the process of drawing up a Fifteen-year plan for atomic power development and this indicates the imperative need for developing at least two or three fabricators and suppliers for each type of equipment required for the nuclear power programme. Whilst we have achieved a reasonable degree of success in getting Indian manufacturers, both in public and private sectors, to supply equipment to the stringent standards of nuclear application, we still have to overcome delays in fabrication to ensure that project schedules are maintained. Generally speaking experience at RAPP and MAPP indicates that the equipment supply determines the schedules of the project and that civil construction is not posing a constraint. Special efforts are therefore required whereby the raw materials which have to be imported can be made available in time. Similarly, the manufacturers should also cut down their manufacturing time. The efforts of the Department in the next few years will be directed towards this end, and towards inducting more manufacturers into the field of fabricating nuclear components. ●

Inflow of Physical Sciences into the Mainstream of Biological Concepts

FROM the very beginning man has concerned himself with quests about the nature of the world he lives in. His early approaches were largely speculative and philosophical, without bringing into focus any clear-cut contrasts or conflicts between living and non-living phenomena. This was unavoidable because man's observations on nature were virtually unassisted by the power of instrumentation and did not therefore penetrate deeply enough to discern basic differences between animate and inanimate phenomena. Aristotle, being both a philosopher and a naturalist, was perhaps the first to explain the nature of life as being due to a vital force peculiar to living organisms and different from all other forces found outside living things.

The development of quantitative sciences in the seventeenth century and the successes that followed their application in unravelling many mysteries in terrestrial and astronomical realms provided confidence that all natural phenomena, living and non-living, are amenable to scientific analysis. Science subsequently progressed along two directions : physical and biological. Significant developments were taking place in chemistry and systematic knowledge was also accumulating in biology. During the late eighteenth and nineteenth centuries, a general interest was awakened for inquiring into the chemical nature of living things. Among the important landmarks in this era, which highlighted the basic unity of biochemistry throughout nature, can be mentioned the pioneering researches of the Swedish chemist Karl Scheel on plant and animal tissues, the studies by Emil Fischer concerning structural chemistry of carbohydrates, amino acids and fats, the discovery of nucleic acids by Miescher, the basic findings of Lavoisier on respiration, the researches of Pasteur and Buchner on chemical transformations during microbial fermentations and the investigations on photosynthesis and carbon dioxide fixation in plants by Horace de Saussure.

Aristotle's vitalism, which dominated biological thought for several centuries, began to lose its prestige. The victorious advances of physics and chemistry in the present century and their inroads into the territories which belonged exclusively to biology are now completely revolutionising our concepts of life processes. As an example, we see how the recent spectacular growth and extraordinary achievements of molecular biology are having their greatest impacts with physics and chemistry. The dominant theme here has been the interpretation in physico-chemical terms of some of the cardinal features of life : replication, development, reproducibility and variation.

Physico-Chemical Probes

INHERENT in current upsurge in biology are two kinds of interactions between physical and life sciences : first, the use of physical methods to study biological phenomena; and, second, the application of physical principles in biological investigations. In turn, these have revealed the manifestation of physical laws in biological phenomena.

The use of physical instruments has indeed played a dominant role in the elucidation of biological phenomena. Thus, the optical microscope has completely revolutionised our idea of the basic structure of living organisms. The 'cell theory,' proposed by the German microscopists Schleiden and Schwann, that all organisms are composed of subunits, resembling one another in the possession of a certain set of organelles and a boundary, and that these entities arise only through division of pre-existing cells, provided a firm foot-hold that has been most helpful to biologists. The establishment of this theory made it possible to deal coherently with what otherwise would have been a hopeless welter of diversity.

Since these early findings, the structure of cells of a bewildering variety of living organisms has been subject to

the scrutiny of microscopic examination of ever-increasing sophistication and resolving power — from the light microscope to the electron microscope. From these studies, there has emerged a composite picture of the cell as a highly complex entity consisting of not just a limiting membrane enclosing a blob of cytoplasm in which the nucleus is suspended, but, instead, a number of variegated, highly organised, convoluted and interconnected structural elements, which vary from organism to organism, tissue to tissue, and cell type to cell type. Yet, within this complexity, some order can be discerned. It has now become abundantly clear that these complex structures hold much of the secret of how cellular processes are controlled both in space and time.

Studies on fractionation of sub-cellular components and their characterisation in terms of composition and function, which are among some of the most exciting, challenging and rewarding fields of inquiry in contemporary biology, are mainly based on the principle that sub-cellular particles, owing to their differences in density, size or shape, sediment at different rates in an applied field of centrifugal force. Our knowledge on how food is transformed into a variety of constituents that make living matter and into energy which is so essential for life processes has come from studies involving a variety of separation techniques based on physico-chemical principles such as differential centrifugation, chromatography and electrophoresis, with their diverse improvements. The instruments developed for this purpose, especially in investigations on biomacromolecules, have far surpassed in their refinement and sophistication corresponding instruments used in chemistry.

Study of metabolic transformations of chemical substances within living organisms, under experimental conditions which cause minimum physiological disturbances, have been facilitated greatly by the use of techniques involving stable or radioactive isotopic compounds. Many important aspects of cellular processes could not have been revealed but for radiotracer techniques. For example, certain cell constituents, which appear to be stationary when analysed chemically, have been found to have active turnover. Crucial roles of some transiently formed molecules in cellular functions, such as short-lived messenger RNAs, could be elucidated only with the help of isotopic tracers.

Refined analytical techniques have also been of value in ascertaining the composition of important macromolecules as well as salient differences among them and for determining the sequence of their building blocks. Such knowledge has greatly helped in establishing some basic tenets of storage and transfer of information. Thus, fingerprinting and sequence analysis of human haemoglobins led to the first identification of single amino acid substitution as the consequence of gene mutations. Differences in amino acid sequences in cytochromes, haemoglobins and other proteins provided deep insights into molecular basis of evolution.

Also, it came to be recognised that the three-dimensional conformation of these molecules, can be of direct importance in understanding biological function. For the elucidation of molecular structure, the method *par excellence* has been x-ray diffraction. Indeed, for certain very complicated molecules in living organisms, it is the only one we know of for determining conformation completely. Its use in this context is fairly new, partly because methods of x-ray diffraction analysis have only recently become sophisticated enough to handle these very complex molecules and partly due to the fact that the concept of structure as applied to biological molecules is only now assuming significance. The theory of x-ray diffraction, which had not hitherto taken into account structural features as are encountered in proteins and DNA, has itself undergone much development — an interesting example of pure physical theory developed in direct response to a biological requirement.

Little is known as yet about the general principles on which the complex structures of proteins are based. The precise manner in which a single string of amino acids coils up in a highly characteristic way is indeed remarkable. While the sequence of amino acids in the protein is determined by the genetic code (nucleotide sequences in DNA), this does not give explicit instruction about the folding of the molecules. It seems likely, although not formally proved, that the sequence of amino acids contains implicitly the information that determines the conformation and that the protein folding occurs spontaneously once the peptide chain is translated in full.

By now, structures of many proteins, for example, myoglobin, lysozyme, carboxypeptidase, ribonuclease, chymotrypsin, papain, haemoglobin, collagen, insulin, etc., are known in detail. Although knowledge of three-dimensional structure is clearly of value in the application of thermo-

dynamic and other physical principles for elucidating allosteric regulation of enzymes, antibody-antigen reactions, and, generally, biological function of proteins in the cell, there are far too many of them and the task of determining structure of even one is quite tedious. Efforts are now being aimed at obtaining information more quickly and more accurately, working with very weak diffraction patterns of large molecules, and analysing these data quickly and automatically. Even so, defining structures of every one of the proteins is going to be a herculean task. Further, there are many proteins, including some very important ones, which have not been crystallised and, with some at least, it may not be possible to do so. Attempts are being made to circumvent these problems by deducting some general principles from a study of the proteins whose conformation and amino acid sequence are known and by applying these to predict, with the help of modern computer techniques, conformation of other proteins from their amino acid sequences.

The Double Helix and Molecular Biology

THE potency of knowledge of macromolecular structure is best exemplified by the famous double helical structure of DNA, conceived by Crick and Watson on the basis of a variety of physical, chemical and biological clues. From Mendelian times, biologists have enquired into the mechanics of hereditary information transfer. Through various phases, some important ground rules were worked out for explaining continuance of traits. Although these achievements, which led to some fundamental generalisations without the aids of physics or chemistry, are by no means small, the infusion of physics and chemistry into genetics, made possible by the discovery of DNA structure, has undoubtedly been among the most important landmarks in the quest for interpreting life in molecular terms.

The structure of DNA provides the basis for our understanding the mechanisms of its duplication, transfer of information in the form of messenger RNA and mutagenisis — which can explain organic evolution. The striking accomplishments emanating from this basic finding are surely the remarkable deciphering of the genetic code and the enzymatic mechanisms of DNA, RNA and protein synthesis. The physico-chemical principles operating in these processes of storage and transfer of biological information are yet to be understood clearly. In this context, the existing theories of chemical reactions have not so far appreciated the importance of weak chemical interactions like hydrogen bonding in DNA. Studies in these directions will not only throw more light on DNA functions but may also reveal some as yet unknown facets of physical chemistry. Likewise, our understanding of the primary step of coupling of transfer RNA to its related amino acid must come from physico-chemical considerations. No doubt the enzyme, aminoacyl transfer RNA synthetase, is involved but there is a strong presumption that this interaction between transfer RNA bearing anticodon and its related amino acid is governed by a mechanism of direct molecular fits. All types of possible stereochemical fits are in fact now being rigorously examined.

Bioenergetics and Biomembranes

AN AREA of biochemistry which promises to unravel some cardinal features of manifestation of physical principles, relates to the function of mitochondria — the subcellular organelles which utilise energy of oxidation by phosphorylating ADP to ATP. Ever since the discovery of oxidative phosphorylation as a major means of energy recovery during respiration in 1938, researches on mitochondrial energy coupling have continued uninterrupted. Recent work is dominated by three concepts of energy-coupling mechanisms : the chemical coupling, chemiosmotic coupling and conformation coupling. Conceptual advances have been greatly aided by electron microscopic studies on ultrastructure of the mitochondrial membrane and by techniques involving freeze etching and fluorescent probes which are useful in studying fast energy-dependent reactions in membrane structures. Other physical methods which have also been used to study energy-coupled structural changes in mitochondria are infrared spectroscopy, optical rotatory dispersion and circular dichroism. The membrane seems indeed a central and indispensable element in energy coupling, and conformational transitions in membrane structure may be expected to hold major secrets in this field.

Biomembranes seem to have very important roles in mediating physico-chemical transformations not only in energy conservation but also in several other important cellular functions, such as active transport, photosynthesis, replication of DNA, etc. There is a growing realisation therefore that fundamental knowledge about their structure

and function is essential for understanding precise relationships between the architecture of living cells and their integrated functions.

Some Formidable Challenges

ALTHOUGH it is rather clear that present day physical sciences are still unable to cope with the complex and diversified manifestations of life, the belief persists that, as Niels Bohr had remarked, 'there are no limitations in the application of physical and chemical concepts to the analysis of biological phenomena.' This confidence is being sustained by a virtually uninterrupted chain of triumphs. It must be remembered that, while physical sciences have their well-tested general laws and universal principles, biology, on the other hand, has elaborate and variegated patterns with all their intricacies and subtleties. If therefore there have been difficulties in reconciling biological behaviour with physical predictions, these have by no means been instrumental for raising suspicions that life is endowed with some element outside the realm of physics. In fact, it is becoming increasingly clear that physical concepts are a powerful fundamental approach for deeper insights into biological functions and that life processes do not represent violation of physical laws but rather their splendid manifestations all along the innumerable phases of evolution.

The present day development of biophysics as a separate discipline has indicated the variety of fascinating ways by which these laws operate at different levels of organisation : molecular, sub-cellular, multicellular and with whole living beings. Although the principles established at cellular levels of organisation should underlie biological functions at multicellular levels, many peculiarities displayed at higher levels of organisation would necessarily call for a separate study of the physical principles involved at each level of organisation. In view of these, quite a few living phenomena such as muscular action, vision, nerve function, etc., have become some of the exciting areas of biophysical research.

Doubtless, there are many serious hurdles to the detailed and explicit analysis, in physical terms, of the many and varied phenomena of biology, which we know are comprised of innumerable elementary events with an extraordinary degree of regulation and co-ordination. Phenomena like differentiation, development, sensory communication and brain function are being explored in terms of physics and chemistry. It is true that these approaches sometimes look hopelessly naive when such abstract language as input-output, black box, information processing, etc., is used to circumvent as yet unknown intricacies of biological processes.

Like biology, physical sciences also encompass a vast range of diversity of phenomena from elementary constituents of atoms to the structure of galaxies. Whereas diversity of physical phenomena finds its unity in the universalities of the physical laws and concepts by which they are manifested, in the realm of biology there is, beyond this, the intricate and interdependent interactions of countless components. It is most remarkable that such variegated organisation with its subtle controls exists within the framework of physical laws. Further inroads of physical sciences into the realm of biology will undoubtedly lead to much deeper understanding of the significance of these fundamental laws. (*Based on the Acharya J.C. Bose Memorial Lecture delivered at the Bose Institute, Calcutta, November 30, 1973*)

Scientific Officer, Bhabha Atomic Research Centre
and Adviser, Department of Atomic Energy

The Story of DNA Repair

DNA is almost always the genetic material of all living organisms. Its organization in a chromosome has evolved from relatively simple structures in prokaryotes to more complex forms in eukaryotes. Even as DNA was first fashioned out of the primeval soup by forces of evolution billions of years back, it must have been subjected to the damaging actions of ultraviolet (UV) light from the sun, for the ozone layer which filters out the UV radiation now had not been formed so long ago. There would obviously be need for repair mechanisms which could restore the essential integrity of the DNA molecules, that were being constantly exposed to UV radiation. Even within the cell, the giant DNA molecules could be expected to have been subjected to various insults. Cellular mechanisms have evolved which repair at least certain types of lesions induced in DNA. It has turned out that the same mechanisms could also be operating to correct the replication errors. However, overcorrection could lead to a very low frequency of mutations. Since mutations are the raw material on which natural selection works, too low a frequency of mutation can be expected to hinder the evolution of a species. Thus the extent of efficiency of repair mechanisms may strike the proper balance between fidelity of DNA replication and the frequency of mutations. By far the most extensively studied repair systems are those that are involved in the repair of UV-induced lesions in DNA.

Mechanisms of DNA Repair

IRRADIATION of bacterial cells with UV light induces many changes in their DNA. The most preponderant chemical *change* in DNA has been found to be the formation of cyclobutane type dimers between two adjacent thymines. It should be emphasized that although other changes in DNA are produced, these do not seem to be as important for the survival of the cell. It has been demonstrated, for example, that if UV-irradiated transforming DNA is exposed to light of shorter wavelength, the thymine dimers are *monomerized* and the biological activity is restored. This mechanism (short-wavelength reversal) which is non-enzymatic may have played an important role in protecting DNA during its prebiotic evolution.

All other known mechanisms of DNA repair are enzymatic. A study of these repair mechanisms has been greatly facilitated by the isolation of UV-sensitive mutant strains. These strains are sensitive presumably because there is in them a blockage in a step in DNA repair. At least three mechanisms of DNA repair have been discovered in bacteria.

These are : a) Photo-enzymatic repair
b) Dark or excision repair
c) Post-replication repair

Amongst these three mechanisms, photo-enzymatic repair is the simplest. A so-called photoreactivating enzyme specifically binds to thymine dimers in DNA and this complex when exposed to visible light enables the enzyme to split the dimers. In *E.coli* this enzyme is coded by a gene which is abbreviated *phr*. Not all organisms possess this system. For example, it is absent in human cells.

A more sophisticated and a more pervasive repair system is the dark repair or excision repair mechanism. In contrast to photoreactivating mechanism, this one does not require visible light to do its job. It is also a multistep system and is presumably carried out sequentially.

The first indication of the molecular mechanism for such a process came from the work of R. B. Setlow and W. L. Carrier in the United States. It was observed that following UV irradiation, wild-type (normal) *E. coli* cells consistently eliminated thymine dimers. N. K. Notani and his co-workers of BARC have produced similar mutants in *Hemophilus influenzae*. In another class of UV-sensitive mutants, thymine dimers are excised but the gaps left by the excision are filled slowly. From combined genetic, molecular and enzymatic analysis of UV-sensitive mutants, the following steps have been postulated in excision repair: Induction of thymine dimers in DNA causes a distortion in the backbone of the helix. This distortion is electively recognized by a UV-endonuclease which makes a nick next to the thymine dimer. An exonuclease then excises an oligonucleotide (a short chain of nucleotides) containing the thymine dimer. The resulting gap is presumably widened and then filled by a DNA polymerase and the final sealing is done by a ligase.

Post-replication repair discovered by Rupp and Howard-Flanders utilizes the cellular recombinational mechanism in which gaps left opposite thymine dimers during DNA replication are filled by insertion of intact segments from DNA strand of the same polarity. Briefly it works as follows : When DNA polymerase (the replicating enzyme complex) duplicates DNA containing thymine dimers, DNA synthesis proceeds past the lesions (dimers) leaving gaps behind in the newly synthesized strands. These gaps are then filled by transfer and integration of intact segments from the old (parental) strands. This transfer will occur if all the genes controlling genetic recombination are able to express themselves. Finally, the gaps left in the parental strands will be filled by repair replication — a copy process that would utilize the intact complementary segment as the template. Sealing would be done as usual by ligase.

Mammalian Repair Systems

ALTHOUGH, all these mechanisms were first discovered in microbes, similar mechanisms have been found in mammals as well.

Photoreactivation mechanism has not been found in mammals except in marsupials which are considered primitive on the evolutionary scale. Excision repair mechanism has been observed only in human and other primate cells. In other mammals, no excision of dimers and very low levels of repair replication have been observed. Post-replication repair by (genetic) recombination in Chinese hamster cells has been reported. However, Lehmann has noted a post replication repair system in mouse lymphoma cells which utilizes a gap-filling mechanism and even though this is a post-replication repair system, it does not involve genetic recombination for filling the gaps.

In the mouse lymphoma cells, gaps are formed opposite UV-induced thymine dimers during DNA replication, but these gaps are filled in by *de novo* DNA synthesis ignoring the presence of dimer in the opposite strand. It is not clear when the nucleotides are inserted in the gap and whether these are put at random or the repair machinery has a way of reading the sequence in the distortion caused by pyrimidine dimers.

Since genes specify the primary structure of enzymes and as the primary structure of a protein (enzyme) determines its function in a major way, it would be expected that the genes involved in specifying repair enzymes would mutate, although with a very low frequency, and such mutations should be observable even in human beings. Indeed, a rare genetic condition called *Xeroderma pigmentosum* (XP) which makes the afflicted individuals very sensitive to sunlight has been found. The condition starts with freckling and ends by producing all types of skin cancers.

At first glance a similarity between a UV-sensitive bacterial mutant and a *Xeroderma pigmentosum* individual would not be obvious. The technique of cell culture permits growth of cells from skin biopsies. Such cells when plated also form colonies like bacteria. Therefore, these cells can be irradiated with UV radiation and their colony-formation survival can be examined. When UV-sensitivity of normal cells is compared with those of XP cells, the XP cells turn out to be about three times more sensitive than normal cells. Not only this but even when UV-irradiated Herpes virus is allowed to infect normal or XP cells, the efficiency of plaque formation is lower in XP than in wild-type cells. Some of the UV-sensitive bacterial mutant strains also are defective in doing this so-called host-cell reactivation.

There are further parallels between UV-sensitive bacterial strains and XP cells. Some XP cells are also defective in excision of UV-induced thymine dimers. They are also found to be defective in replication repair. There are of course quantitative variations amongst XP individuals in the extent to which they excise thymine dimers or do replication repair but qualitatively they can be grouped together. What relationship there is between UV-sensitivity and carcino-genicity in XP individuals remains yet to be determined.

Repair Birth Defects: Their Prevention

In at least two families, the occurrence of XP individuals in the progeny was correlated with consanguinity. In an Indian family, four out of six children had this condition. In such high-risk families genetic counselling against begetting additional children after the first afflicted one is diagnosed would be helpful.

In addition, a revolutionary technique called transabdominal amniocentesis has been developed which allows *in utero* diagnosis for certain genetic diseases. A therapeutic abortion can then be performed if the test is positive. The analysis on amniotic cells for XP condition

hinges on the observation that following UV irradiation, one gets repair replication in normal and heterozygous cells but not in XP cells. During this replication, bromodeoxyuridine can be incorporated in normal cells but not in XP cells. DNA containing bromodeoxyuridine can be broken by 313 nm light wherever there is bromodeoxyuridine inserted. The result will be a shift from larger-sized DNA to smaller-sized DNA in normal cells but not in XP cells. Such a test has been perfected and can distinguish between normal and XP cells. Needless to say that such a test would be performed only in families with high-risk for *Xeroderma pigmentosum*.

Damage by Ionizing Radiations

THE frequency of UV-induced mutations in *E. coli* strains with defective recombination system is very much lower than in wild type strains. This indicates that UV-induced premutational lesions may be changed to mutations through the errors introduced by recombinational repair process.

Compared to what we know about the repair of UV-induced damage in DNA, we know very little about the repair of damage induced by ionizing radiations. Ionizing radiations also produce very many changes in DNA. These include single and double strand chain scissions, base damage, cross-linking etc. Single-strand breaks are not generally lethal but double strand breaks are lethal in phages and bacteria. Double-strand breaks may be repaired in *Micorcoccus radiodurans* and in mammalian cells. Base damage may also be important for survival but its role remains to be determined. X-ray induced pre-mutational lesions also seem to require recombinational repair processes to yield mutations. Both point mutations as well as deletion mutations have been induced in *Neurospora* by ionizing radiations. The spectrum seems to be dose-dependent.

I like to end this brief story of DNA repair with a general comment. It should be mentioned that repair of DNA was not presaged even after the double-helical structure of DNA became known. The experiments begun on this aspect by radiobiologists seemed to have bearing on nothing else. Yet, in a short period of a decade or so, DNA repair has its place along with the key genetical functions of replication, recombination and mutation. More importantly, DNA repair may have governed the rate of evolution of all species by protecting, preserving and changing DNA from prebiotic times to the present day.

Director, Bio-Medical Group
Bhabha Atomic Research Centre, Trombay
and
Dr. R. D. Ganatra
Officer Incharge, Radiation Medicine Centre,
Bhabha Atomic Research Centre

Nuclear Medicine : 25 Years

NUCLEAR MEDICINE is concerned with the use of artificially produced radioisotopes for diagnostic, therapeutic and investigative purposes.

These radioisotopes are usually radioactive counterparts of many stable elements participating in the physiological processes of the body. When used as tracers, they enable study of living processes in dynamic terms.

The main medical applications of radioisotopes today are largely concerned with the following functions : (1) assessment of the functional activity of an organ — which is done by measuring the amount and rate of accumulation of a radioisotope in the organ, *e.g.* uptake of radioiodine by the thyroid gland; (2) Scintigraphy, where the distribution of a radionuclide in an organ is charted for evaluating the functional integrity of each part of the organ; (3) estimating *body spaces* and exchangeable *electrolytes e.g.* total body, blood volume, exchangeable sodium etc.; (4) measuring *blood flow* to various regions and organs of the body *e.g.* cardiac output; (5) for measuring *absorption* of various labelled nutrients, *e.g.* vitamin B-12, etc. (6) for *in vitro* estimation of hormones and vitamins *e.g.* insulin, growth hormone; (7) for studying the kinetics of various blood cells; (8) for knowing the metabolic turnover of physiological substances *e.g.* protein turnover; (9) for therapy *e.g.* use of radioiodine in thyrotoxicosis and thyroid cancer, where this radioisotope is administered in high doses to destroy pathological cells.

Though artificially produced radioisotopes have been in use in medicine for over two decades and Nuclear Medicine is well established in advanced countries, its development in India began with the growth of the atomic energy programme in the country. For an effective nuclear medicine programme in any country both radioisotopes and electronic instruments should be easily available. Self-sufficiency in this area has been achieved to a great extent in India, most of the clinically used radioisotopes being produced in the reactors at the Bhabha Atomic Research Centre (BARC), Trombay.

Production and distribution of radioisotopes on a commercial scale in this country was taken up by the Isotope Division of BARC in 1961. In the past 10 years, about 35 radiopharmaceuticals, both in elemental and labelled form, have been made available by BARC to medical laboratories in India and abroad. India today has advanced capabilities in regard to the variety and quantity of radiopharmaceuticlas that can be manufactured for medical applications.

THE production of electronics instruments for medical purposes is done at the Electronics Corporation of India Ltd., a public sector undertaking of the Department of Atomic Energy, at Hyderabad. R & D efforts at the Electronics Division of BARC, which is a pioneer in this line, is also continuing.

At present, the country has about 70 radioisotope laboratories, most of them attached to general hospitals. There are two large Nuclear Medicine Institutions : the Radiation Medicine Centre of the Bhabha Atomic Research Centre, and the Institute of Nuclear Medicine and Allied Sciences of the Ministry of Defence at New Delhi. Besides these two, many outstanding medical institutions such as the All-India Institute of Medical Sciences, New Delhi, the Christian Medical College & Hospital, Vellore, the Banaras Hindu University, and most medical colleges of Bombay have radioisotope laboratories.

In 1963, soon after the supply of radiopharmaceuticals on a routine basis became possible, the Department of Atomic Energy established the Radiation Medicine Centre (RMC) at Bombay. In the last 10 years, the RMC has come to enjoy both national and international recognition. Recently, both the World Health Organisation and the

International Atomic Energy Agency have recognised it as a Regional Reference Centre for South East Asia in the field of Nuclear Medicine.

The RMC provides free service facilities for investigations and treatment with radioisotopes primarily to create awareness in the medical fraternity of the potentialities of Nuclear Medicine. Nearly 10,000 patients avail of this service annually.

The RMC also offers training programmes for building up medical and paramedical personnel. For the last 8 years, it has conducted a 6-week basic training course on "Medical Uses of Radioisotopes" every year. So far a total of 113 trainees have taken advantage of these courses. The Centre also has a short advanced and intensive course on a specific clinical radioisotope technique every year. The University of Bombay has accorded recognition to the 'Diploma in Radiation Medicine' for medical graduates and 'Diploma in Medical Radioisotope Techniques' for science graduates, conducted by Bhabha Atomic Research Centre. The University of Delhi is another university which has recognised this discipline. A one-year academic programme leading to these qualifications has been started at the Radiation Medicine Centre this year.

The number of radioisotopic investigations per year per 1000 of the population in Greater Bombay works out to 2 per 1000, a figure comparable to that in Japan and New Zealand. This favourable figure for Bombay has become possible because of the facilities at the Centre and also because of the training programme available to the doctors in this region. Besides the Radiation Medicine Centre, Bombay has seven other Nuclear Medicine Units. Of course all the four teaching medical institutions in the city have their own radioisotope laboratories. Some more well equipped radioisotope laboratories are expected to come up in the near future.

In the last few years, there has been a major shift in the trend of medical applications of radioisotopes. This has been mostly in scintigraphy. The trend now is to use short half-life generator-produced radionuclides. Precise quantitative information about the functions of many endocrine glands is obtained by *in vitro* procedures like radioimmunoassay. The increasing use of short-half-life radioisotopes, and of *in vitro* procedures has resulted in considerable reduction of radiation exposure of the patient during diagnosis.

With the use of the short half-life radioisotopes, the radiation-exposure of the patient is negligible which makes possible extension of radioisotopic investigations to children and pregnant women, the two groups which were hitherto not covered because of radiation risks involved.

Along with the use of short half-life radioisotopes, the character and design of the scintigraphic equipment has changed. The modern scanner accomplishes a scan image of a large organ at a speed which is 5 to 10 times higher than what was possible with the scanners in the Sixties. This speed is possible because an optimum amount of radioactivity can be administered to a patient without undue risk as the radioisotopes used have a short-half-life. This is of special significance to our country as faster scanning techniques permit effective handling of a larger number of patients in a shorter time.

Cyclotron-Produced Radioisotopes

THE use of cyclotron-produced radioisotopes has just started in a routine way at many centres in the world. Radioisotopes which show promise in this respect are: ^{18}F, ^{123}I, ^{67}Ga, ^{15}O, ^{13}N, ^{111}In etc. ^{131}I the most widely used radioisotope at present has several undesirable physical characteristics. With the increasing availability of ^{123}I, the use of ^{131}I for diagnostic applications will gradually decrease. When the Variable Energy Cyclotron at Calcutta becomes operational, it may become possible to undertake production of some radioisotopes which have a relatively longer half-life.

^{133}Xe can be produced both in the reactor and in the cyclotron, but it is in gaseous form at the time of irradiation. It can be subsequently dissolved under pressure in normal saline solution for clinical use. Its use is gradually gaining recognition for lung function studies. There could be wide-spread demand for it in India because of the multitude of respiratory problems in the country.

The next decade may well be said to belong to radioimmunoassays. These and similar procedures based on the principle of saturation analysis are done *in vitro*, without administering any radioactivity, and with a minimum of instrumentation, to obtain precise quantitative measurement of blood levels, hormones, vitamins and other important physiological parameters. ^{125}I is used instead of ^{131}I because it gives long shelf-life of the labelled compound and because its use involves less radiation hazard. Radioimmuno-

assay techniques however require scrupulous care and high technical skill.

Future Needs

The greatest contribution of Nuclear Medicine is to diagnosis. Diagnostic uses of radioisotopes cover a wide field and embrace almost all the clinical disciplines. Some of the diagnostic procedures are simple and some extremely complex. The range at present covered in our country is restricted to simple procedures and only a few laboratories here have achieved any degree of sophistication in their work. There are many clinical problems specific to this country where radioisotopes would provide great help. However, very few laboratories have attempted to look beyond the conventional thyroid problems.

It is obvious that for future expansion of nuclear medicine in this country, existing radioisotope laboratories will have to enlarge the range of their work and many more laboratories will have to come up to exploit the benefits offered by radioisotopes in medical diagnosis and research.

It will be economic and efficient if small radioisotope laboratories attached to teaching hospitals function as centralised units with persons working full time in the area of Nuclear Medicine.

In addition to these small hospital radioisotope laboratories, the country would need more centres like the Radiation Medicine Centre of BARC to undertake the full range of diagnostic and therapeutic applications of radioisotopes, to provide training to medical and paramedical personnel, and to develop new procedures and research into clinical and associated fields of nuclear medicine.

Exposure to radiations has a definite risk both to the patient, the doctor and the general public. While hazards from conventional techniques are easily identifiable, those arising from improper and indiscriminate use of radiations and radioisotopes may come up after a number of years and some, in future generations. It is therefore essential that the medical doctors and paramedical staff are stringently certified after an extensive theoretical and practical training in the various aspects of the application of radioisotopes to human beings. The institution of a diploma in nuclear medicine for medical doctors and a similar diploma for non-medical personnel by the University of Bombay is an outcome of the special requirements of this relatively new technology.

If we aim at having one nuclear medicine department in every hospital in the country, the demand for trained personnel is going to be high, and training programmes should be increased and made available in a large number of centres. ●

The Philosophical Motivations of a Scientist

I BELIEVE that unless every scientist has some philosophical motivations in approaching his research problems, he will never be a complete scientist. It is only rarely that deep and fundamental contributions to science have been made without a philosophy behind them. There is certainly no such thing as a complete man without a philosophical component in his make-up. But in stressing the importance of a philosophical motivation for a scientist, it is essential to define the exact meaning of philosophy in this context. There are several possibilities. Let me list some of them :

(a) It could be the scientist's attitude to things mystical or to religion.

(b) It could be his attitude to the arts such as music, painting, literature, etc. and the importance of these in the theory of knowledge.

(c) It could be his attitude on the origin and purpose of life not necessarily constrained by the laws of Physics.

(d) It could be his attitude to the foundation of science based on Logic and Mathematics.

On a lesser plane, the philosophical attitude of a scientist could also be defined as his attitude to the methods of interpretation, or use of techniques in the study of natural phenomena. The reactions of a scientist to the purpose of science, discovery for its own sake, or discovery leading to an important technology can all be termed as philosophy of science. In recent years the contributions of science to weapons of destruction, to spying etc. have been discussed on philosophical grounds, particularly in the West. But there has been so much humbug in this that it is difficult to associate these as part of philosophy. This list is by no means complete and is given here so that I can express my views based on my experience on some of the points.

Unfortunately, the scientist in India has been largely guided in his philosophy of science by Western attitudes. It is only in the last few months that a feeling has come about that there exists a scientific community in India which is willing to appreciate ideas not necessarily in line with something that exists in the West, and that if there is an idea suitable to the Indian mind, it is not necessarily wrong even if it is not straightaway accepted in the West. All this is reasonable in view of the fact that Western philosophical standpoints themselves have been changing positions, sometimes in diametrically opposite directions and often not even consistently.

The Attitude of a Scientist

WHAT should be an Indian scientist's attitude towards religion and things mystical? Our background goes deep both in time and quality in pointing out that whatever be the truth component of religion or, using a more modern phraseology, the spiritual aspect of man — it is an inescapable part of our structure. In fact, I could say that the Rig Vedas and other ancient texts are the first attempts to systematize scientifically this craving of man. The fact that it has survived all these thousands of years shows its inherent strength. The question is: how do we readjust this spiritual craving to make it consistent with modern thinking about the need for it ? It should be noted that the discoveries of modern science could easily have been classified as some normal part of the philosophical method, but for the fact that their applications have led to technological advances which have the potential to change the very nature of man itself. It is not because recent advances have helped to reduce human labour that we give a special place to science in philosophy — in fact from time immemorial this has been happening — but because through science it may be possible to change the fundamental character of man, his biological structure and his thinking, his genetic behaviour etc. The situation is somewhat similar to the metamathematical paradox provided by the sentence : "I am a liar" which, besides stating a fact, also says something about the validity of the sentence itself.

If such be the case, what attitudes should a scientist take towards (a) organised religion and (b) to spiritual—mystical impulses that come naturally to some human

beings and which are perhaps acquired by others. In the lowest forms these impulses may appear as superstition, black magic etc. We could include in its more sophisticated manifestations the arts — music, poetry, painting etc. Unfortunately many scientists indulge in such a variety of these activities that it reminds me of one of the sayings of Ramakrishna Paramahamsa : "Man is like a fly, one moment it sits on the choicest of foods, and another on garbage."

Organised Religion Obsolete?

ORGANISED religion has many reasons for its existence. In India, occasionally it appears in its practical form as a protection from social injustice. But, in many cases it has become a vested interest in the hands of a few who have used it for very unpleasant forms of exploitation. In its loftier forms, it has acted as a storehouse of culture, and at times has led to periods of great artistic activity and provided a moral force to society thereby giving a power of survival to certain social and cultural systems. It has also inspired much human intellectual activity. But, in spite of all this, it has also led to great periods of darkness, cruelty and downright foolishness. We have to ask ourselves today : do we need organised religion such as that which existed during the Moghul and the British days to protect our culture ? Do we need our Brahmins to preserve our ancient learning ? Do we still have to burn incense and involve ourselves in various rituals (handed down to us more by habit) to propitiate the Gods ? Do we still feel spiritually unsatisfied if we do not go through this ritual ? To me the scientific answer is quite straightforward. The older functions of organised religion are over, but its spiritual values will always remain with us. Whether we are going to obtain this ecstatic experience through music which is something I approve of, being a student of music myself, through painting, which is popular in India and is available to many people mainly because it seems to be an art that can be pursued without much training at least in the beginning, or just reading old poems of Bhakti, one of which I have recently attempted to translate into English, ("The Mukundamala" of Shri Kulasekhara Alwar — 10th Century) is a matter of choice or individual taste. We will have to draw the line somewhere, for we must not forget that people in the past used to get some sort of spiritual satisfaction by seeing widows being burnt alive. And in some places even now goats are slaughtered in scores for this purpose. In drawing this line we must bear in mind that a highly scientific approach to religion is not for all. Sometime back at a meeting of the National Committee on Science and Technology, I stated that the more sophisticated aspects of science are not useful for solutions of all the problems of social development and that I would not teach Quantum Mechanics to all and sundry however successful it is in explaining microscopic phenomena, as much as I will not teach Sanskrit to everybody. In a similar sense, religious experience in its most sophisticated form cannot be for all, while at the same time it cannot be allowed to sink to such levels that it could dement the thinking power of young persons who have not yet exercised their opinion in these matters and who have not had enough experiences to select their own form of spiritual experiences. I am specially worried at the mental laziness that can engulf a young man when exposed to indiscriminate religious experiences.

A Dichotomous Scientist

IT IS sometimes said that an over-scientific approach to religion can lead to a very materialistic view of life. Modern Western attitudes are often quoted as an example and the reaction to it in the form of Hippyism. I am no particular admirer of Western attitudes or even of its very affluent form of life, and feel that modern Western interest in Hindu thought is their discovery that Hindu thought allows for greater freedom of spiritual experiences than Christian and Islamic thought. It is my view that even as India is entering a period of involved scientific thinking and technological advance, the Vedas and the work of the Acharyas will satisfy religious needs if only we can divest ourselves of the ritualistic aspects of religious experience. In this way I believe that the rarified spiritual experiences obtainable through music, poetry and the other arts will be greatly enhanced.

It is not necessary to be tied to the written word of the Vedas or of any other ancient work, but the spiritual experience of those who wrote them is readily transferable. I am not sure that one actually requires a Guru for this purpose. If some people need a Guru, and if there is one such, who because of his greater personality is able to transfer his experiences to another, I have no objection. But false Gurus there are many and we must be beware of them — especially those who mix up spiritual experience with the material world of Physics. I refer to the writings

of one of our esteemed colleagues who has tried to make a case out for materialisation by Gurus. This has to be taken seriously as it comes from an eminent person who has held many responsible positions. When he takes up this position we would like to ask him (a) Do you really believe that the material world and the spiritual world are so closely connected that we can repeat the following question (asked by the late Shri K. M. Munshi in Bhavan's Journal some years ago): If mass and energy are connected by Eistein's equation, could there also not be a relation between spirit and energy in some similar form ? Surely Physics is unable to answer this question since nothing about the spirit is definable in the physical sense except that it exists. In any case, if a definition is attempted, it would break up the very corner stones of physics — the conservation laws. (b) Do you permit yourself a dichotomous process of reasoning — one for Physics, and one for matters concerning the spirit, and are willing to suspend all principles of Physics when talking about the spirit. (c) If by the use of spiritual forces one enters the material world, can one stop there, and refrain from asking further questions belonging to the material world, such as : can spiritual energy produce only objects of religious value to middle-class Hindu societies and nothing else ? This can lead to strange contradictions.

The attitude of a scientist to the arts is on a different plane as no conflicting situations are created. The spiritual world reigns supreme and is independent of anything material. In fact, one can claim the same status for pure Mathematics. Beauty, excitement and spiritual ecstacy are all there. Starting from well defined axioms a logical super structure is built which is awesome in its majesty. No one of course can deny that even mathematics is not entirely free from inconsistency. The Godel theorems have shown that mathematics has its limitations. It is not at all strange that H. Weyl states that mathematics is very much like music: it is what it is and gives pleasure because it suits the human mind. But at no stage is there any conflict with the material world. The Godel theorems do not seem to upset the foundations of Physics.

The purpose and origin of life has been a subject of organised speculation ever since the Vedas came to be composed, and we are still nowhere near the answer unless we accept that explanation that the whole thing is an accident — a question of probability. In any case, even this is not a complete answer. Modern biologists say that the whole phenomena of life belongs to the world of Physics, though the physicists who previously made such assertions are not at all certain now. Ever since the formulation of Quantum Mechanics, the physicist's confidence in assertion of the type advanced by biologists, has weakened. In fact, though we all know that Quantum Mechanics works, we are not at all sure of its consistency. The epistomological basis of Quantum Mechanics is far from satisfactory. During the last few decades the explanation of physical phenomena has been transformed from dynamic description to discovery of symmetry laws. It is my personal view that Physics has got into a rut because our definition of invariance is too restricted and we require the more powerful methods of differential geometry on a manifold for the complete understanding and unification of Physical laws. The transformation from dynamics to a mathematical description is a welcome one as it provides a greater freedom of approach and may lead to an understanding of the structure of life through the revelation of new laws, not easily understood on a dynamical basis. On the religious side no one is going to be impressed nowadays by legendary theories of the creation of the universe. But who can deny the beauty, imagination and power of these stories. They are so good that one would like to believe they are even true. But what is, and what we want to be real, are not the same thing. Whatever be the future of science, it will be at its most exciting period when it begins to answer questions of the type : how does a collection of long chain molecules produce sensations of beauty, introspection and spiritual ecstacy ? I would somehow like to believe that this is impossible.

The Purpose of Research

IN emphasising the importance of philosophy, I am constrained to bring to your attention the other side of it, an attitude common among Dictators. It is said the conqueror of Constantinople immediately after the conquest announced that the first thing his armies should do was to destroy all the philosophers. A similar statement is said to have been made by Himmler — if we are to believe Schellenberg.

The day-to-day work of a scientist requires considerable philosophical guidance even when a lot of his time is spent in very mundane matters — even house-keeping. To avoid being too tedious, I will skip over the scientific

philosophy in his day-to-day work, but will say a few words about the attitude of a scientist on the purpose and aim of research fully aware that it is not quite related to what has been said above. But it seems too important to omit in a discussion where the scientist has to ask himself : is my work worthwhile ?

We must recall from the history of science that it emanated from the requirement of daily use such as counting, measurement etc. Till recently arithmetic taught in school was essentially a business-man's arithmetic. It is only now that elementary mathematics has taken a deeper meaning. I have also been told that during the middle ages, people in England could only get training in addition, and for training in more complex arithmetical operations had to go to Europe, which in turn had received the methods of computation from India. Early Indian mathematics owes its impetus to business and calendar prediction. It is therefore not strange that people should always ask what is the use of pure science. During the renaissance of Indian science in this century, great pride of place was given to pure science — science for its own sake, in full consonance with the Hindu theory of knowledge. I recall that when I started research, there existed a contempt for those who did any technological or applied Physics. During the 50's and 60's, the theory of elementary particles was considered as supreme knowledge and any other branch of physics was looked upon as being not too important. At least we who did not work in these exciting fields were full of an inferiority complex. Now things have changed suddenly and a time has come when I have to apologise for introducing any research activity of a pure nature in any discussion on science planning.

The Place of Pure Research

DURING the last few months there has been a great hue and cry concerning the social relevance of scientific activity in India. The insistence on social relevance is another example of indiscriminate grafting of Western ideas on our approach to science. There are all sorts of schools in Europe and America producing a new breed of persons who call themselves Science of Science Scientists. These countries after indiscriminate spending in research, mainly resulting from the cold war race are now looking around for a more sane approach. Of course, nobody denies that science must be put to work to improve the lot of the masses. The fault is not that science is not available for such use, it is only inadequately administered and organised. Our supply of water to the cities and villages requires no high science. The maintenance of our sadly managed power stations means more training of personnel. Our slum clearance is essentially a political problem and the poor functioning of our industry — a problem of labour and management. Whereas our universities are lagging behind as they do not have sufficient resources or encouragement to take up interesting research to keep bright young people active in creating new ideas — new conceptions, we are leading ourselves into great danger by imitating a passing Western fancy by running down pure research. I quote Prof. C. V. Raman when I say that research for its own sake is the salt of the earth. We have never spent indiscriminately on pure research here as elsewhere — so why attack it and give it second priority ? I will go to the extent of saying that our nuclear programmes are flourishing, our power stations are in full operation and, even if on one occasion one faltered it was set completely right by our own people because of the strong R&D we have with a large component of pure research.

I put it to you that the very survival of our culture is due to our insistence on knowledge for its own sake. Therefore, we must all with one voice stop any move to remove from the pedestal our cherished principle that has sustained us all these years. We must have more pure research but it must be more cooperative and larger in scale. This alone should be our philosophy to the aim of research. If anything of an applied nature comes about, which lover of pure research will stop him from exploitation, it is in his own interest to speed up the application of basic discoveries to technology. (*Talk delivered at the Seminar on "Science and Society," at the Indian Institute of Science, Bangalore, June 21, 1793).*

This issue incorporates the February issue. There will therefore be no separate February '74 issue of *Nuclear India*.

Edited and published by Jagannath Sharma, Publications Officer, Dept. of Atomic Energy, Government of India. Chhatrapati Shivaji Maharaj Marg, Bombay 1, and printed by him at Conway Printers Pvt. Ltd., 167c, Dr. A.B. Road, Worli, Bombay 18.

Registered No. R. N. 9002/62

NUCLEAR INDIA

VOL. 12, No. 7 PUBLISHED BY THE DEPARTMENT OF ATOMIC ENERGY MARCH 1974

The Narora Project

Design Modifications For a Seismic Site

ON January 13, the Prime Minister Smt. Indira Gandhi unveiled a plaque at Narora to mark the commencement of work on India's fourth nuclear power station.

Narora is a sparsely populated region in the Bulandshahr district of western Uttar Pradesh. The Station will be located on the right bank of the river Ganga where the new Narora barrage is situated and the lower Ganga Canal takes off. The plant site is about 5 km. from the Narora barrage.

Like the Rajasthan and Madras Atomic Power Stations, Narora will also have two reactors of the CANDU (Canadian deuterium uranium and pressurised heavy water) type of 220 MWe (net) each. The station will be using natural uranium as fuel, unlike the Tarapur plant which uses enriched uranium.

by P. N. Arumugham
Power Projects Engineering Division
Department of Atomic Energy

The Narora project is estimated to cost about Rs. 210 crores, of which about Rs. 30 crores will be in foreign exchange.

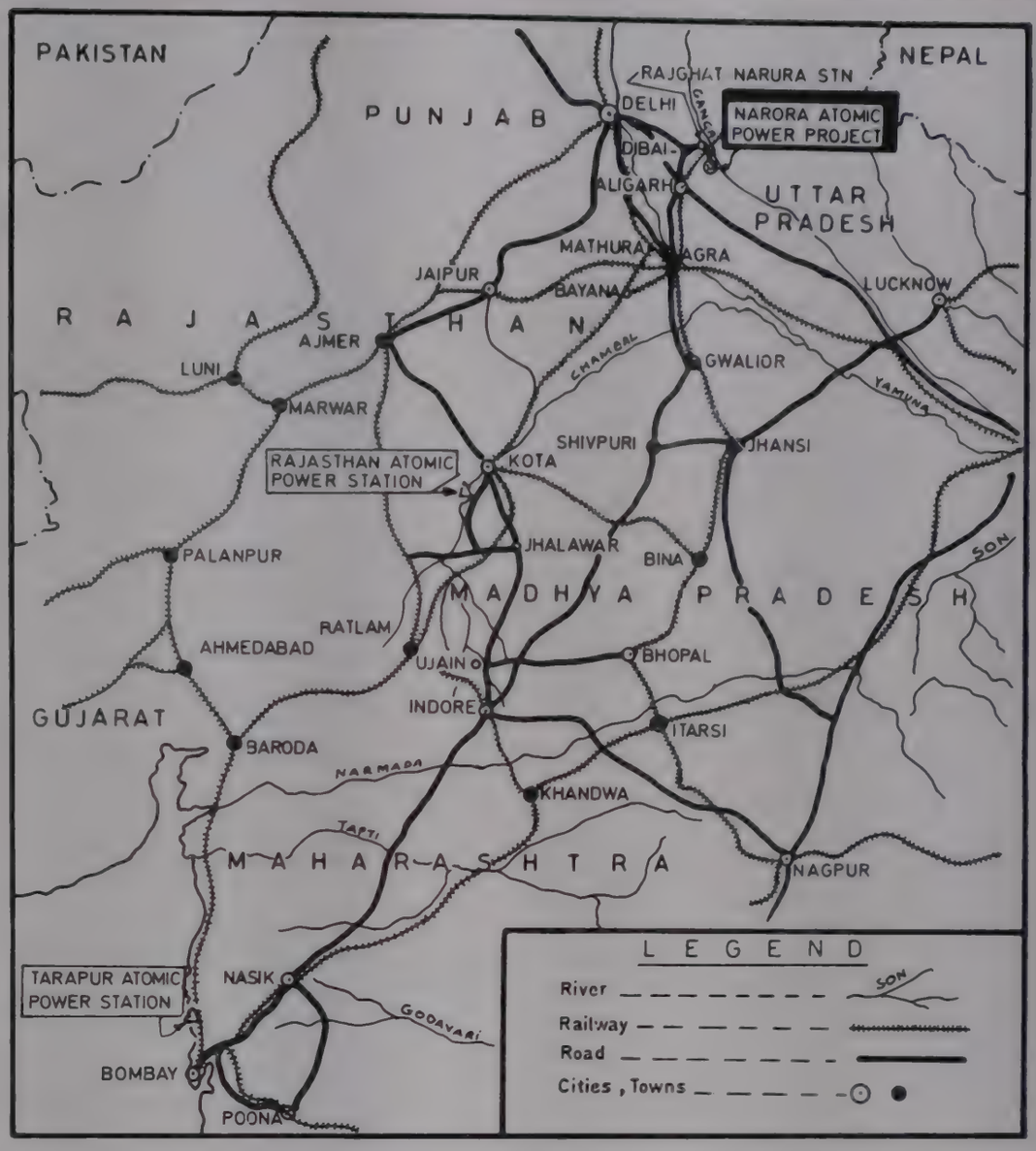
Moradabad Fault

Though the Station has CANDU-PHW reactors, its nuclear portion has to be modified to meet special site requirements. As the site falls within the seismic zone, the design of the plant has to provide for safe operation under seismic conditions. One of the predominant geological features close to the site is the Moradabad fault which is known to be connected with seismic disturbances recorded south-east of Delhi, near Moradabad. The fault is located about 40 kms from the site. The seismicity of the site requiries detailed studies for assessing the effect of seismic forces on the structures, and the dynamics of vibrations that may be induced on equipment. The structural and equipment designs will incorporate features considered necessary as a result of these seismic studies.

Some of the significant design modifications visualised for the nuclear portion of the Narora Station are outlined here.

The basic containment philosophy for the Narora reactors is the same as that for MAPP; both use the modified vapour suppression concept for limiting the pressure-rise in the containment. However, one of the major modifications in the design of the Narora containment pertains to the double containment system consisting of a primary containment volume, which encloses major heavy water equipment and systems, along with a

(Continued on page 2)

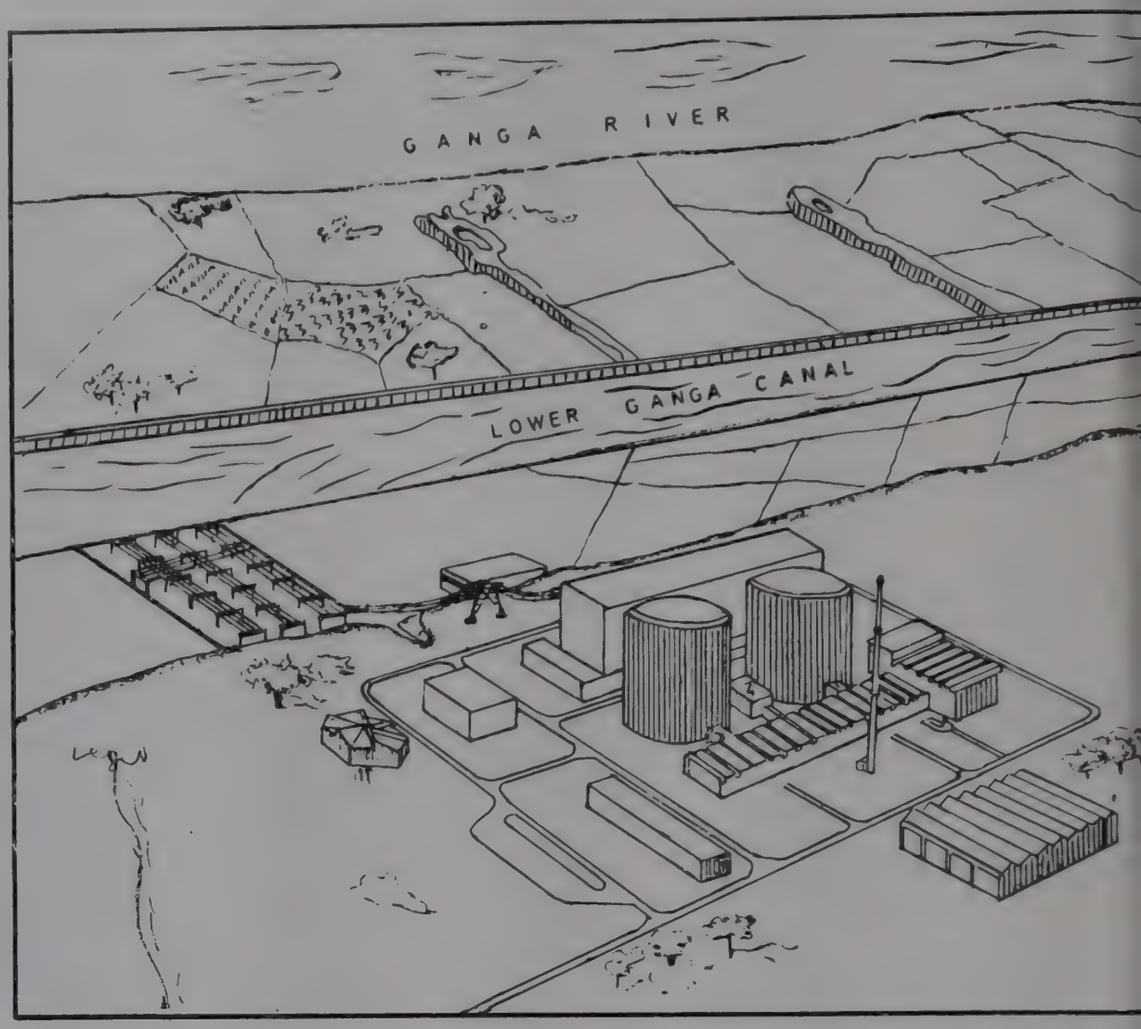


Major Changes in Reactivity Control System

(Continued from page 1)

secondary system containing a secondary volume where a minimum of heavy water release can be anticipated. This modification also offers better accessibility to a part of the reactor building. The double containment philosophy also helps in meeting the stringent leakage rate requirement stipulated by regulatory authorities. The primary containment system consisting of an inner concrete enclosure, will be designed to a maximum pressure of 1.15 kg/cm^2 (16.35 psig) which may arise in the event of an accident. The double containment will be specified for a maximum leakage rate of 0.1% per day, which is lower than the 0.1% per hour rate specified for the RAPP reactor.

The alluvial soil conditions at site, where sound rock is not available within reasonable depth for fixing the foundations of the structures, call for a system of concrete piles and base slabs to support the reactor building walls and other structures.



The Narora Station will be located on the right bank of the river Ganga where the new Narora Barrage is situated and the lower Ganga Canal takes off.

Integrated Design

Another significant modification lies in the vault arrangements. While retaining the essential features of a central calandria vault flanked by two fuelling machine vaults, one on either side, the Narora design provides for radiation shielding around the reactor core by water filled in the calandria vault. The calandria vessel is held immersed in the water pool contained by the vault concrete walls. This arrangement is intended to simplify several auxiliary circuits. For instance, air-cooled thermal shield plates are eliminated since the water surrounding the calandria provides the neutron shielding, which task is done by the air-cooled thermal plates in the earlier reactor designs. The water-filled vault also requires suitable modifications to the end-shield-calandria combination which will now become an integrated design.

The seismic studies conducted to examine the design of RAPP or MAPP type reactor buildings and associated equipment revealed that the design of the reactor components, such as the calandria and the end-shield, would require modifications. The present design of the reactor building however does not present insurmountable problems. These studies have indicated that during seismic disturbances, the movement of the calandria in a plane perpendicular to the axis of the coolant channels has to be restricted, and the relative movement of the end-shields and the calandria must necessarily be prevented. This has been achieved by visualising the two end-shields and the central calandria as an integral assembly with end-shields firmly supported by, and grouted in the concrete of the calandria vault. By this integral design, it is also possible to lower the elevation of support of these assemblies, besides ensuring that relative movements between the lattice positions in the end-shields and those in the calandria do not arise. With the adoption of this design, the calandria vessel becomes a simple stainless steel shell with only nozzles and outlets for reactivity mechanisms and piping connections. This integral design will be detailed and finalised after development efforts and prototype work in several areas are completed.

Major Changes

Major changes in the reactivity mechanisms and the associated reactivity control system are being incorporated in the Narora design. The moderator dump and the cover gas balance sys-

tems, which form essential features of RAPP and MAPP reactors, are proposed to be eliminated since this will simplify the calandria design and fabrication. The Narora design will provide for shut-off, regulating and booster rods. The immediate result of these modifications is that the total number of penetrations at the top of the calandria will be about 30, as against 8 in the RAPS or MAPS calandria. The primary shutoff system will consist of several liquid poison tubes, while the secondary shutoff system will be in the form of perforated liquid poison headers through which adequate quantities of poison material can be injected as required. The fine regulating rods and coarse shim rods will consist of stainless steel absorber material driven in and out of the reactor core by suitable drive mechanisms. The booster system, designed to provide reactivity for over-ride of xenon poison following reactor shut down, is expected to be provided by plutonium booster rods. The preliminary design, as evolved, will be followed before firming up the detailed designs.

Besides the modifications briefly described above, there are several other design changes that may arise from equipment and layout considerations. For instance, the steam generators will be of integral design with vertical 'U' tubes in shell arrangement, somewhat similar to those used in the PWR type reactors. Four such steam generators and associated primary coolant pumps will form the primary heat transport system, with two sets of these equipment installed at either end of the reactor.

There are several changes in the moderator system, both due to the elimination of the dump system and due to the introduction of shut-off systems using liquid poison. Various auxiliary circuits are modified, one of the design criterion leading to the removal wherever this is possible, of light water equipment and system from the reactor building. There are changes in the fuel handling systems. All these design changes and development tasks will have to be carried out when the engineering work gathers momentum.

The site of the Narora Station, about 5 kms. from the Narora Barrage.

plant, no major changes are envisaged. The turbo-generator steam and feed water cycle is likely to be the same as that adopted for MAPP, and the turbo-generator unit to be supplied by Bharat Heavy Electricals Ltd., will also be identical to those being made for MAPP.

There may be some design changes arising from equipment layout or local electrical power system considerations. For instance, the question relating to possible direct link of the Narora Station with the UP 400 KV grid now under construction has to be studied, and suitable decisions have to be taken. The cooling water system, though considerably simplified by circulating fresh water drawn from the lower Ganga Canal, may still have to be designed taking into account the silt load in the Ganga river water. Hydraulic model studies are in progress at the Central Water and Power Research Station, Khadakvasla.

Trace Elements

(Continued from page 5)

one may use spark source mass spectrometry or atomic absorption spectrometry. In most of the cases a tiny bit of hair is all that is necessary.

In summary, hair is a unique specimen in many ways. Apart from its use in forensic and medical sciences, it may also be advantageously used in problems of archaeology and geochemical reconnaissance.

REFERENCES

(1) A. A. Gordus, Environmental aspects of trace metals in human hair, University of Michigan (1973).

(2) W. W. Harrison, J. P. Yurachek and C. A. Benson **Clinica Chimica Acta, 23,** 83-91 (1969).

(3) J. Tinker, New Scientist **51,** 728 (1971).

(4) V. S. Venkatavaradan, Radiocarbon and Indian Archaeology (Eds. D. P. Agrawal and A. Ghosh), Tata Institute of Fundamental Research, Bombay pp. 476-479 (1973).

(5) V. S. Venkatavaradan, **Current Science 42,** 477 (1973).

TRACE ELEMENTS

By V. S. Venkatavaradan
Tata Institute of Fundamental Research, Bo

A description of the conventional fields of app elements in hair, and a summary of possible a such as geochemistry and archaeo

THE hair is a unique biological material typical of the individual who possesses it. Major variations in the quality of the hair among races is well-known : short and crisp woolly hair is representative of negroids; wavy or smooth and silky hair typifies caucasians, and straight, long and coarse hair goes with mongoloids. The knowledge that the hair is highly individualistic has been used in crime detection on an empirical basis. Until recently, the parameters one compared, in general, were the colour, thickness and the waviness of the hair. However, modern nuclear techniques of analysis have established that the elemental distribution of human hair varies from individual to individual and this has made hair a very important objective tool in forensic science. It is now fairly clear that the distribution of elements in hair is as unique as one's fingerprints.

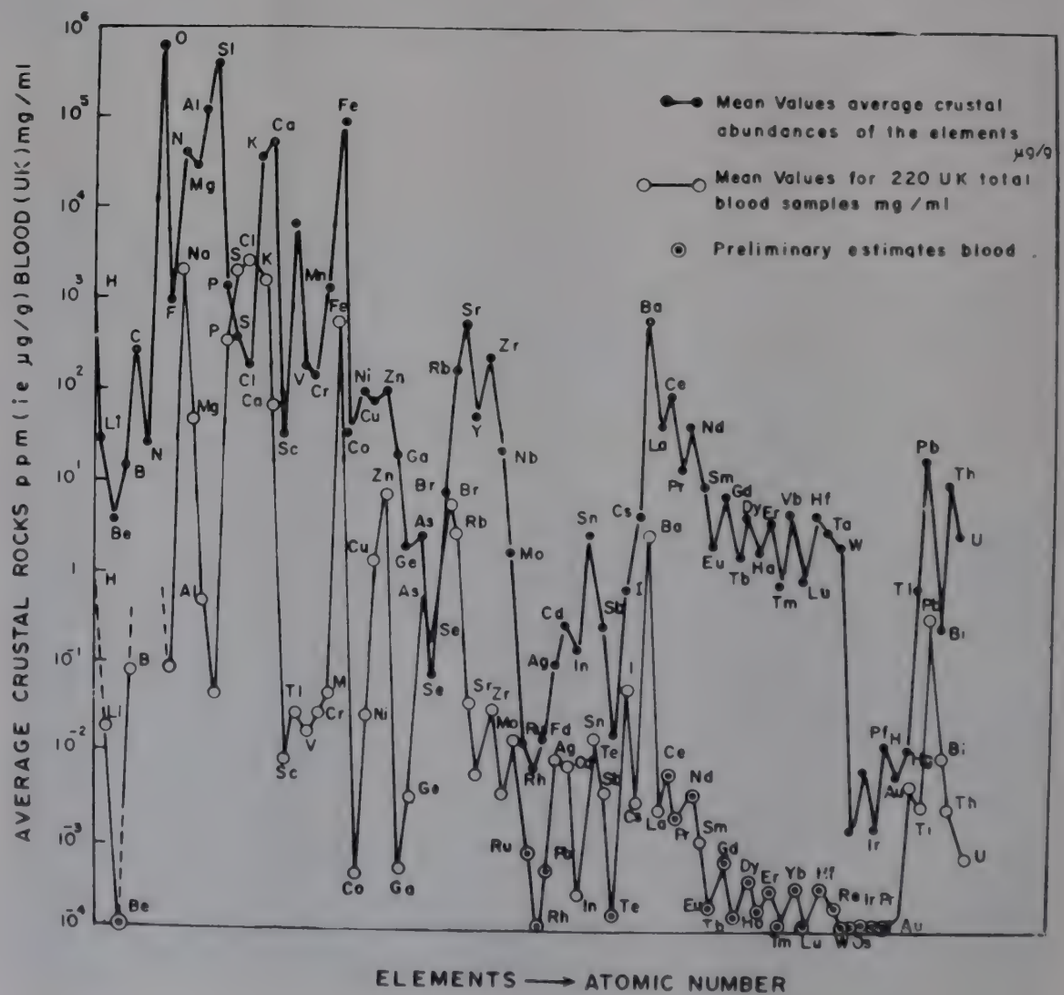
In the neutron activation technique, a specimen of the hair obtained from the site of crime is irradiated with a flux of neutrons in a reactor, along with the hair of the suspected person. The elements that are activated emit characteristic γ-rays which can be analysed over the whole spectrum of energies of the γ-rays. (See *Nuclear India* June/July 1973). A comparison of the two spectra will show whether the two specimens have the same origin or not. This technique however has not yet been accepted as evidence in a court of law, and may be used only as an investigative tool.

Medical Applications

It has been shown that zinc levels in the hairs of individuals known to have a zinc deficiency are *significantly* lower than normal values. With oral zinc sulphate therapy, the zinc levels in the hair increased. Analysis of human hair for different pathological cases may form an empirical basis for the diagnosis of many diseases — even before the symptoms begin to appear. The ease of analysis of many trace elements in hair is due to the fact that hair concentrates many of the minor elements by a large factor. For instance, mercury concentration in human hair is about 250 times that of the human blood.

Analysis of lead and mercury in human hair may be able to show the amount of lead and mercury poisoning in the patients. Many of the pollutants may also be looked for in hair which will give an index of the pollution in the environment. In fact, by studying the amount of trace elements in hairs over different periods of time, Prof. Adon A. Gordus of the University of Michigan, U.S.A., proposes to find out the variation of these pollutants as a function of time. The study is expected to help in finding out the increase in intake of harmful elements due to industrialisation.

Before we discuss the possible applications of hair for archaeological and geochemical problems, one should understand the elemental distributions in rocks, human blood and hair. A comparison of abundances of minor elements in crustal rocks and in the blood samples of about 200 UK citizens showed a remarkable correlation. Except for the major components of blood (C, H, O, N), and of rocks (Si), the similarity is very well seen. Rocks of different regions have different elemental distribution. The human blood will reflect the rocks (and also the soil) of the region in which the


Mean Values average crustal abundances of the elements µg/g
Mean Values for 220 UK total blood samples mg/ml
Preliminary estimates blood
AVERAGE CRUSTAL ROCKS ppm (ie µg/g) BLOOD (UK) mg/ml
ELEMENTS ⟶ ATOMIC NUMBER

HAIR

of minor
s in areas

people live. Since, as we have mentioned earlier, the hair concentrates the minor elements, it will reflect the variations of these elements in a better or amplified way. Thus we find that the hair is truly representative of a geographical region tagged by its trace elements in a unique way.

Other factors which affect the minor elements in blood are occupation, food habits and of course diseases. One finds a high level of lead in the blood of a traffic policeman (due to automobile exhaust) whereas silicon and aluminum (major constituents of soil) are in excess in an agricultural labourer. These patterns are also expected to be shown in the human hair.

Geochemical Reconnaissance

A survey of human hair from regions which are known to be rich in certain ores (such as, for instance, gold in Kolar) may be made to see whether it does in fact reflect in an appreciable way the ore content of the soil. It is already known that the soil, vegetation and ground water in an area reflects the nature of ores in a region. It seems likely that human hair is similar to the vegetation of the area in this respect and one can make what is called a "geo-chemical reconnaissance" of a large area for possible ores using human hair. The method of geochemical reconnaissance based on trace elements in hair is similar to geobotanical prospecting (use of plants in interpreting geological ore sites) and hence worthy of an illustration. Some plant species grow more extensively near an ore site because they need for their growth one or more of the elements in the soil. For instance, the plant species *viola calamineria* (yellow violet) grows consistently in zinc-bearing soil. The species *Gypsophila Patrinii* is found in places where the copper content in the underlying rock is high in copper, even upto one per cent. When the species is absent, one finds the copper content very low (less than 10 ppm); these plants are called indicators of their respective ore bodies.

Sometimes certain plants grow exclusively in regions containing a particular ore even though they need not require them for their growth. Species like *Hutchinsia alpina* grow in zinc-rich soil because they reject it while other species that absorb it are poisoned.

Whereas different species of plants are needed to predict the occurence of different ore bodies, the hair of the local population may be able to show in a single analysis all the possible ores in a given location. Animal hairs (like wool) may also be advantageously used to infer the geochemical properties of a region. Activation analysis of hair may lead to the direct detection of high concentration valuable ores. However it may also be useful in revealing indicative patterns of grouping of trace elements which, together with geological field relations, may lead to the location of important mineral deposits.

Archaeological Inferences

The property that hair reflects (1) the rocks of the region (2) eating habits and (3) diseases etc., may be used in archaeological problems as follows :

It is possible to trace movements of human population from one region to another (if the concerned regions differ markedly in their trace element contents) from analysis of ancient human hair. It should also be possible, in principle, to distinguish various ethnic groups in a population.

Since the trace elements in hair depend on the diet, it may be useful in understanding the food habits of different civilizations. There may be a marked deviation in percentage of certain elements present, say between vegetarians and non-vegetarians. It may even be possible to distinguish rice eaters and wheat eaters. One could also answer the persistent question : 'Did the Aryans eat beef ?'

Every epoch has its characteristic ailments. The middle-ages (6th-14th centuries) were dominated by ills of common people such as plague, leprosy and epidemic neuroses. The period of the Renaissance was marked by syphillis, while in the Romantic period there was a preponderance of tuberculosis. The 19th century witnessed a tremendous increase in industrialisation which brought with it a plethora of industrial diseases, general nervousness and neuroses of many kind. These may leave their stamp on the human hair by enhancing or depleting certain elements. Further, there are deficiency diseases like camp-fever, scurvy and ergotism, and luxury diseases like gout, dropsy and hypochondriasis — human hair could tell whether a people lived in luxury or conditions of want and malnutrition.

The technique of measuring trace elements is well advanced. Apart from neutron activation technique,

(Continued on page 3)

TRACE ELEMENTS IN HAIR

FIELD OF APPLICATION	PROPERTIES USED
1. Forensic Science	Uniqueness of elemental distribution. Enrichment of poisons like arsenic.
2. Medical Science	Enrichment or depletion of characteristic elements.
3. Pollution studies	Enrichment of pollutants
4. Geochemical Reconnaissance	Enrichment and indicative patterns of minor elements.
5. Archaeology	All the properties mentioned above.

International Laboratory of Marine Radio

WE use the seas and oceans as a repository for the waste products of industry and the run-offs from agriculture. It has become clear however, that the sea's capacity to transform or absorb these wastes is not unlimited and that controls are essential. International as well as national action must be taken.

The nuclear industry and the IAEA have been concerned for more than a decade to ensure that the rapid growth of nuclear power would not have harmful effects upon the seas and on life within them. One of the IAEA's first steps in this regard was to set up an international laboratory at Monaco in 1961 to study the impact of radioactivity on the marine environment, about which very little was then known.

The International Laboratory of Marine Radioactivity was founded in 1961 under a tripartite agreement between the International Atomic Energy Agency, the Government of the Principality of Monaco and the Institute Oceanographique, Fondation Prince Albert /er de Monaco. The programmes undertaken by the Laboratory from its conception concern both basic and applied research.

Its premises are on several levels, built into the rock face of the cliff which stretches from the large rock outcrop on which the Royal Palace and old city of Monaco is built, down to the sea level below.

The studies being undertaken by the Laboratory centre on :

1. The chemical behaviour of radionuclides of various chemical states in the sea water.
2. The distribution and accumulation of radionuclides by the various components of the marine biota.
3. The interchange of radioisotopes between the sea bottom and the bottom water.
4. Intercalibration and standardization of methodology for marine radioecological studies.

There is growing interest in working on concentrations of plutonium in the ocean, as this will probably be increased as a result of the fast breeder

STATEMENT OF OWNERSHIP

Statement of particulars regarding NUCLEAR INDIA, as required to be published under Section 19-D, sub-section (b) of the Press and Registration of Books Act read with Rule 8 for the Registration of Newspapers (Central Rules, 1956 as amended).

1. Place of Publication	Department of Atomic Energy, Chhatrapati Shivaji Maharaj Marg, Bombay 400 039.
2. Periodicity of Publication	Monthly
3. Publisher's Name Nationality Address	Jagannath Sharma Indian Department of Atomic Energy, Chhatrapati Shivaji Maharaj Marg, Bombay 400 039.
4. Printer's Name Nationality Address	Jagannath Sharma Indian Department of Atomic Energy, Chhatrapati Shivaji Maharaj Marg, Bombay 400 039.
5. Editor's Name Nationality Address	Jagannath Sharma Indian Department of Atomic Energy, Chhatrapati Shivaji Maharaj Marg, Bombay 400 039.
6. Name and Address of the Owner	Department of Atomic Energy, Government of India. Chhatrapati Shivaji Maharaj Marg, Bombay 400 039.

I, Jagannath Sharma, hereby declare that the particulars given above are true to the best of my knowledge and belief.

March 1, 1974 (Sd.) JAGANNATH SHARMA

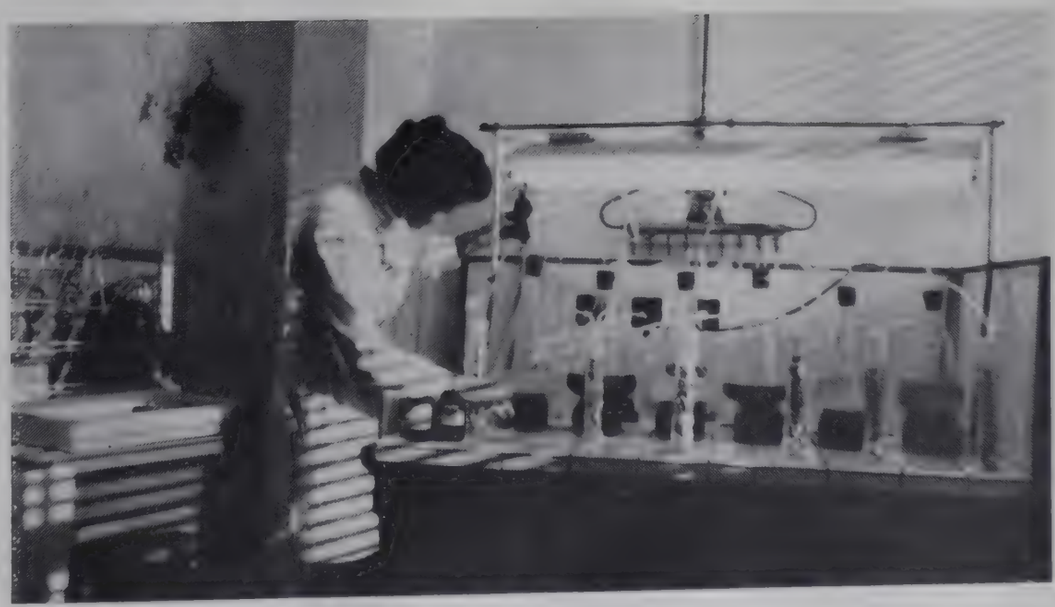
Windows on three floor levels set into the rock face, are part of the offices and laboratories of the IAEA Marine Radioactivity Institute.

vity, Monaco

reactor programmes. These reactors will probably be situated near the coast, and fuel-reprocessing plants will also be situated along the coastline.

The possibility of increased off-shore designed nuclear power plants means the necessity of off-shore re-fuelling, all likely to add to the pollution. Population can likewise be expected to increase in the same areas where it has shown growth in previous decades — that is, along the coastline. There are proposals from some international, as well as national organizations, that the activities of the Laboratory be expanded to include investigations on the most important non-nuclear pollutants using, in principle, nuclear techniques.

(IAEA Bulletin Vol. 15 No. 4)



Top: A marine sediment core obtained from one of the national oceanographic institutions which cooperated with the Laboratory in a programme on radionuclide behaviour in ocean and coastal sediments. Marine sediments have a great ability of binding fallout and waste radionuclides : In shallow seas most of the radioactivity will be found in the sea bottom.

Middle: Analysing the concentrations of stable elements in marine samples (water, plants, animals, sediments) with the recently acquired atomic absorption spectrophotometer.

Bottom: Water-cooled nuclear and conventional power plants use chlorination of the cooling water to avoid the growth of organisms in the cooling circuit. A study is being made at the Laboratory to investigate the effects of chemical biocides to the environment, as a side effect of the increasing need for cooling water.

Installation of Supporting Systems for Cyclotron Starts

THE Variable Energy Cyclotron Laboratory building at Bidhan Nagar in Calcutta is ready, and installation of supporting systems has started.

The Cyclotron, which is being built by the Bhabha Atomic Research Centre (BARC), will be a national facility for advanced work in nuclear physics, and for the controlled direct irradiation of biological and agricultural products.

Equipments for the main systems of the Cyclotron are being fabricated at various centres in the country. The 262-tonne steel core of the main magnet has been completed at the Heavy Engineering Corporation, Ranchi. The six sector pole-tips are also ready for assembly at Ranchi. Fabrication of all the ten pancakes for the main coils of the magnet has been completed by Heavy Electricals (India) Ltd., and the three-meter diameter aluminium casing assemblies for the main coils, manufactured by a Baroda firm, are ready. The RF panels and their drive system have been fabricated at the Central Workshops, BARC, Trombay. Manufacture of the RF resonator tank and the Dee and the Dee-stem is being done at the Garden Reach Workshops, Calcutta and Central Workshops of BARC respectively. Ten prototype NIM standard electronic modules for the data processing system have been made in the Electronics Division of BARC.

Fast Breeder Test Reactor Will Be Most Important Facility at Reactor Research Centre

THE Reactor Research Centre (RRC), Kalpakkam is being set up next to the Madras Atomic Power Project. The most important facility in this Centre will be the Fast Breeder Test Reactor which will provide experience in the design, construction and operation of a plutonium-fuelled, sodium-cooled fast reactor. It will also serve as an irradiation facility essential for developing fuel for the large fast breeder reactors of the future. The other facilities at the Centre will help in the [illegible] operation of the Fast Breeder Test Reactor, and use of the test reactor for studies in connection with future fast breeders. The Centre will also have a Pulsed Fast Reactor which will be a unique facility for research in physics, especially in solid state studies and radiation damage.

With the completion in May 1972 of the zero energy fast reactor, PURNIMA, at Trombay, the Pulsed Fast Reactor programme has moved forward as the PURNIMA core is a prototype of the one to be used in the Pulsed Fast Reactor at RRC. Experiments now in progress at Trombay will lead to the finalization of the design parameters of the Kalpakkam Pulsed Fast Reactor.

Production, Supply of Radiation Sources Records Increase at BARC

THE sale value of radioisotopes, equipment and services rendered by the Bhabha Atomic Research Centre during the year totalled Rs. 56 lakhs, an increase of about 20 per cent over 1972-73. More than 34,000 radioisotope consignments were despatched during the year, including some 23,900 consignments for medical applications, and 2,200 consignments for industrial applications. Radioisotopes, labelled compounds and equipment were exported to several countries including Australia, Austria, Denmark, France, Indonesia, Malaysia, Nepal and Singapore. Special mention may be made of the export of a gamma chamber-900 unit to Sri Lanka under the UNDP Programme.

The most significant achievement is the development of an indium generator which provides ^{113m}In, a short-lived radioisotope currently being used in nuclear medicine for scanning of placenta, brain, liver, kidney etc. A prototype ^{113m}In generator was prepared and demonstrations were given at the Fifth Annual Conference of the Society of Nuclear Medicine, held at Berhampur, Orissa. Development of ready-to-use kits for the preparation of ^{113m}In labelled compounds has also been standardized for kits for the preparation of ^{113m}In-gelatin complex and ^{113m}In-DTPA. Work is in progress to establish methods for the preparation of ^{113m}In-labelled microspheres.

The production and supply of large radiation sources also increased. A total of 2,12,000 curies of cobalt-60 in the form of various sources was supplied to users during the year, a six-fold increase over the corresponding figure for last year. These include seven sources of a total activity of 22,400 curies for teletherapy units in hospitals, and 21 source rods of a total activity of 1,25,000 curies for the initial charging of the ISOMED radiation sterilization plant. About 4,300 curies of iridium-192 in 430 consignments were supplied for industrial radiography.

Project RAPPCOF (Rajasthan Atomic Power Project Cobalt Facility), a cobalt-60 handling facility under construction at the Rajasthan Atomic Power Station, is nearing completion. The mechanical equipment for the recovery of cobalt from absorber assemblies is being fabricated. The facility is expected to be commissioned in 1974.

ISOMED, the Radiation Sterilization Plant for Medical Products (UNDP/SF Project) at BARC, Trombay has been commissioned. The mechanical equipment of the irradiators has been installed, and the plant has been loaded with 1,25,000 Ci of cobalt-60. Intensive marketing efforts are being made to promote the use of radiation sterilization techniques in industries, and the Panoramic Batch Irradiator (PANBIT) at Trombay has helped achieve this objective. With the close cooperation of pharmaceutical concerns, medical equipment manufacturers and others, and using the PANBIT facility for irradiating small consignments of medical products, it has been possible for many manufacturers of medical products to carry out feasibility studies, product evaluation and test marketing of radiation sterilized products. Advice on choice of materials, packaging, product development etc. has been provided to a large number of industries.

Support Industries Strengthen Base of Nuclear Programme

THE Indian Rare Earths Ltd., the Electronics Corporation of India Ltd. and the Uranium Corporation of India Ltd., are the three industrial units administered by the Department of Atomic Energy.

The Indian Rare Earths Ltd. (IRE) has been functioning since 1950, and operates the Mineral Sands industry in Manavalakurichi and Chavara, and the Rare Earths industry at Alwaye. It also produces thorium at Trombay.

During 1973-74, the Company registered further improvement in its turnover, foreign exchange earnings, and net profit. Its profit during the year is estimated to be approx. Rs. 50 Lakhs.

The production of rare earths chloride was normal and the Company was able to meet its export commitments. Export realisation of this product in the year under review touched the Rs. 1-crore mark. Trisodium Phosphate produced in theAlwaye Plant was sold in the domestic market as in the past. The Company has established a firm footing in the Japanese market for rare earths fluoride, a product recently introduced in the export market. The export earnings from beach sand minerals reached an all time high this year.

The Electronics Corporation of India Ltd. (ECIL), Hyderabad, was formed in April 1967 and gradually took over the work of the Electronics Production Unit of the Bhabha Atomic Research Centre. It produces on a commercial scale a large variety of nuclear instruments, control equipment, electronics components etc. developed by the Bhabha Atomic Research Centre and the Tata Institute of Fundamental Research, Bombay.

In 1972-73, the sixth year of its incorporation, the ECIL's operations resulted in a profit of Rs. 113.43 lakhs, after charging depreciation of Rs.47.31 lakhs, interest of Rs. 28.98 lakhs, research and development expenditure of Rs. 14.83 lakhs, and social overheads of Rs. 15.02 lakhs. After providing Rs. 17.75 lakhs for taxation, other appropriations, and transfer to General Revenue of Rs. 8.50 lakhs, the Corporation has paid a maiden dividend at the rate of 5 per cent on paid-up equity amounting to Rs. 18.75 lakhs.

The Uranium Corporation of India Ltd., Jaduguda, was formed in October 1967. It is responsible for the development of the Uranium Mine and the operation of the Uranium Mill at Jaduguda.

During 1972-73, the Corporation made a net profit of Rs. 17.22 lakhs after providing Rs. 58.02 lakhs for depreciation and Rs. 7.61 lakhs towards interest on long term loans.

The work of deepening the Jaduguda Mine is progressing satisfactorily. However, production is short of target due to constraints in ore hoisting and shortage of working faces. Construction of the plants for recovery of molybdenum and copper as byproducts from Jaduguda ore and for recovery of uranium from copper tailings is progressing satisfactorily.

Nuclear Fuel Complex

THE Nuclear Fuel Complex (NFC) at Hyderabad is an integrated nuclear fuel manufacturing facility set up by Indian scientists and engineers with indigenous know-how to meet the fuel requirements of the country's nuclear power stations.

The Complex has seven chemical and metallurgical plants *viz.,* (i) the Zirconium Oxide Plant, (ii) the Zirconium Sponge Plant, (iii) the Zircaloy Fabrication Plant, (iv) the Uranium Oxide Plant, (v) the Ceramic Fuel Fabrication Plant, (vi) the Enriched Uranium Oxide Plant, and (vii) the Enriched Fuel Fabrication Plant to convert raw materials and minerals such as zircon sand, nium hexafluoride to finished RAPP and TAPS type fuel elements, and other zircaloy reactor components and hardware such as calandria tubes, coolant tubes, fuel channels, end plugs, and spacer wire, etc. The flow sheets for most of these plants have been established by extensive R & D work at the Bhabha Atomic Research Centre, Trombay.

Based on the knowhow generated in the Chemistry and Metallurgy Divisions of BARC, a Special Materials Plant has been added to the Complex for the production of 18 different high purity metals and materials for the growing electronics industries.

As part of the diversification programme, a 2,000 tonne/annum Stainless Steel Seamless Tube Plant, and a 7.5 tonne/annum Titanium Pilot Plant are also being added to the Complex.

Considerable progress in the operation of the various plants at NFC has been made during the year. Some of the highlights and achievements for the year are : (i) Commissioning of the Enriched Uranium Oxide Plant for the conversion of uranium hexafluoride to uranium dioxide powder and of the Enriched Fuel Fabrication Plant for the production of Tarapur fuel elements. (2) Successful fabrication and supply of 30 enriched fuel assemblies to the Tarapur Atomic Power Station, and 560 natural fuel assemblies to the Rajasthan Atomic Power Project. (3) Trials on optimisation process parameters at the Zircaloy Fabrication Plant for the production of RAPP and TAPS type fuel tubing, RAPP type coolant tubing and production of zircaloy hardware such as end-plates, end caps and wire. (4) Optimisation of process parameters and regular production of 15 different high purity electronic grade materials at the Special Materials Plant. (5) Improved production of zirconium oxide and reactor grade zirconium sponge respectively at the Zirconium Oxide and Zirconium Sponge Plants. (6) Commissioning of the Titanium Pilot Plant, and commencement of trial production of commercial grade titanium sponge.

(Continued on page 11)

Energy: Systems, Development and

Shri H. N. Sethna, Chairman of the Atomic Energy Commission, discusses here the status of energy, its sources and consumption in the world context and urges a fresh look at the pattern of its generation and consumption, especially in India. This text is excerpted from his J. N. Tata Lecture at the Indian Institute of Science at Bangalore on March 29.

THE history of civilisations all over the world is the history of energy. The magnitude, type and the nature of use of energy inputs throughout the ages have determined the life styles, economic prosperity, military power and the social mores of various countries at different points of time. From muscle power (human or animal) and heat energy (burning of wood), man has slowly graduated to the use of mechanical and chemical energy conversion systems and electric power. The rate and extent of energy use has influenced the population structure and land use patterns. The progressive development of agricultural technology, use of metals, textiles, trade, shipbuilding, architecture, roads, cash crops, small industries, heavy industry, transportation, recreation, home appliances and extensive irrigation are manifestations of the increasing use of energy in many forms. What is often described as the revolution of rising expectations is essentially the revolution of energy use.

The scale of energy utilisation is so great that society's reliance on energy is very high. Energy can no longer be considered as an isolated economic and social problem. The generation of electricity from very large stations has resulted in many interdependencies among areas and regions. Any disruption in the supply of fuel or energy in an advanced society today, will result in a serious dislocation of economic activities and the life styles of people. The impact of the recent oil crisis is a telling example of our dependence on energy.

In any country today, economic development is not feasible without increase in energy supply. The GNP of many countries has a direct correlation with the energy consumed. In the past, a decrease in energy supply has resulted in the decline of civilization and the standard of living of people. Energy, in short, is the key indicator of socio-economic development.

Current Energy Resources

IN the modern world, energy is derived largely from fossil fuels : Coal, Oil and Natural gas. Hydro-electric power is becoming relatively less important and nuclear power is becoming more significant. I would like to review briefly the use of these resources in India.

Coal is our most important fuel. Proven reserves in India are approximately 83 billion tonnes. From a current annual production of 70 million tonnes, it is proposed to increase it to a level of 135 million tonnes by 1978-79. Though most of the coal has high ash content, it is available in abundance. The main users of coal are the railways, power plants, manufacturing industries like steel, cement, textiles, paper etc.

Our total oil reserves amount to about 130 million tonnes. The current annual consumption rate is around 23 million tonnes. Its uses are mainly distributed among road transport, industrial heating, production of fertilisers and domestic fuel. The current production is only 8 million tonnes and the gap in supply is met through imports. Our natural gas resources are about 1.86 million cu m. and is mainly used for industrial and domestic heating in a small way. During the fifth plan no great increase in production of these resources is possible.

The hydro-electric potential that can be economically exploited, is about 41000 MWe. The current production is about 9000 MWe and by 1978-79, it is proposed to increase it to 16000 MWe. Hydro-electric power can be used largely for seasonal requirements of irrigation etc.

The current installed capacity of nuclear power is 600 MWe. During the 5th plan, this would be increased to about 1000 MWe. With the currently available uranium resources and reactor technology, the total potential for nuclear power is about 5000 MWe. An active atomic mineral exploration programme is planned through which it is expected that more uranium resources would become commercially exploitable. Simultaneously, the development of breeder technology is being undertaken in an accelerated manner so that more power can be generated from the existing uranium and thorium resources; but this is a long term possibility.

In non-commercial fuels, cow-dung, firewood and vegetable wastes constitute the major categories. These are mainly consumed for domestic use in rural and semi-urban areas. While a precise estimate of the demand for these fuels cannot be made, one can say that the use of these fuels will continue to rise at a slow rate in these areas.

Current resources for energy from solar power, fuel cells, geothermal, wind or tidal sources are very limited and energy from these sources will not increase in an appreciable manner in the next 5-10 years. While solar power holds promise as a long term solution to the energy crisis, a great deal of R&D work remains to be done to

olicies

make it commercially viable on a large scale.

Current Energy Systems

ENERGY is being generated presently from various sources mentioned earlier, at home, in the farm, at the factory, in vehicles and at power stations. The supply of commercial fuels is largely undertaken by government agencies and large corporations. Electrical energy is being genera ed and supplied by State Electricity Boards which are responsible for this task within each State. The use of electric power as a share of total energy consumed is increasing rapidly. Currently, it is about 20% and is expected to increase to 30% by the end of the century. Power stations with single units of 200 MWe are being operated now. Most of the State electricity grids have been formed by interconnection of power systems so that integration and optimisation of power generation and distribution can be done at the State level. A few zonal grids are also operating with some exchange of power between the States. Attempts are being made to form a national grid by the end of this decade so that an overall optimisation can be achieved. Such optimisation will have economic, environmental and social advantages. The distribution and utilisation of various types of fuels can be done in the best possible manner with necessary interfuel substitution by the interconnected grids. Increase in system integration of electric power will continue in the current decade, while other forms of energy will probably be generated and consumed by individual farms, homes, factories etc., without any overall optimisation and integration.

Energy Policy at Cross Roads

WE have reviewed briefly the current energy scene in India. The standard of living of our people is low and nearly

World population and use of primary energy

	1950	1960	1970	1980	1990	2000
Population (10^9)	2.50	3.00	3.60	4.35	5.20	6.10
Uses of primary energy						
(10^9 TCE)						
Solid fuels	1.57	2.20	2.42	2.90	3.75	5.00
Liquid fuels	0.64	1.32	2.85	5.00	8.00	10.00
Natural gas	0.27	0.63	1.43	2.40	3.00	4.00
Hydro power	0.12	0.25	0.47	0.70	1.10	2.00
Nuclear power	—	—	0.03	0.80	3.15	8.00
Total primary energy	2.60	4.43	7.20	11.80	19.00	29.00

TCE = Tonnes of coal equivalent at 7×10^6 K. cal. per tonne of coal.

Source : **IAEA Bulletin, October 1973.**

Installed Generating Capacity and Power Production

Year	Installed Cap. (million Kw)	Total Energy Generation (million Kwh)	Kwh/Kw Installed
1947	1.9	4935	2740
50-51	2.3	6574	3000
55-56	3.42	10777	3260
60-61	5.66	20123	3840
65-66	10.17	36825	3960
71-72	17.00	65214	4000

Source : **Oil Commentary, 1973.**

Investment In Power Supply Industry

Period	(Rs. in crores)
Pre-Plan Period	190
First Plan	302
Second Plan	525
Third Plan	1381
Annual Plans (1966-69)	1253
Fourth Plan (Estimate)	2523
Fifth Plan (Proposed)	3323

Source : **Planning Commission.**

40% of the population lives below the poverty line. The current economic recession has probably caused a worse situation. Ours is not a high energy society. However, political compulsions and the social aspirations of our people demand that we produce and consume more energy in the future to improve the quality of life of the large masses of our population. There is fragmentation and inefficiency in the production, distribution and consumption of energy in our country. Urban areas consume energy in a large measure. The distribution of energy consumption like the distribution of income and wealth is largely skewed in favour of the urban areas. To promote development and social equality in the future, energy policy appears to be a very potent instrument. The current oil crisis and the resultant price increases are now compelling us to review our energy policy in the light of our social goals.

The policy options open to us are, inter alia, in the choice of technologies, interfuel substitution, pricing, energy allocation and environmental quality. While choice of social goals is a political process in our country, we find this choice takes place at various points of time by the force of events in an unarticulated manner and not by conscious planning. Even if the goals are defined, the alternative strategies that are open, are not often explicit. I would like to share with you here some of my thoughts about these alternatives in energy policy and the impact of these alternatives on the choice of social goals themselves.

Some Considerations in Energy Planning

AS I have mentioned earlier, energy planning is related to social preferences. At an individual level, the preferences for example can be about the type of comforts (heating, lighting, appliances etc.) at home, the nature of entertainment and recreation, the kind of labour-saving aids, the mode of transportation and extent of mobility etc. The criteria of choice among the alternatives would be cost, safety and the quality of life desired. At a societal level, the preferences could be about environmental quality, technology alternatives (for example centralized versus local generation of power, type of conversion of energy and distribution alternatives), alternative uses for the fuel (*e.g.* oil as a feedstock for fertilizer or as an industrial fuel or as a transportation fuel), siting policy (based on land use policy, nearness to consumption centres, aesthetic values, availability of cooling water and ecological aspects), and legal requirements (regulatory standards and statutory needs).

Another main consideration in our country is the regional distribution of energy resources. A balanced regional development policy would make it imperative that location of energy production centres would have to be distributed among the regions in an equitable way. This problem assumes a much larger dimension in the international context. The current oil crisis orginating from West Asia is a manifestation of the highly unequal distribution of fuel resources.

Another point to be kept in mind when planning for energy is that energy problems can be solved only in a relatively long term framework. The use of energy is directly related to individual life styles and it would take a long time to change these. Moreover, design and construction of modern power stations takes about 7-12 years in India and hence the permanent solution of energy problems can only be attempted in a long range span.

Energy planning in India has been largely a choice of series of projects with different technologies based on economic criteria. The assumption of linear growth rate for demand in a region is used to determine the needed supply from different electric power generating stations, keeping in mind the use of other energy forms. For electricity projects, cost-benefit analysis is normally used to rank various projects in the order of the economic

Energy Consumption in Million Tonnes of Coal Equivalent

	Commercial Energy						Non-commercial Energy				Grand total
	Coal	Lignite	Oil	Hydro	Nuclear	Total	Dung	Fire-wood	Veg. waste	Total	
1968–69	69.50	2.25	84.30	15.20	—	171.25	19.70	135.10	32.6	187.40	358.65
1973–74	93.50	4.00	152.60	22.63	4.23	276.96	22.60	155.10	35.1	212.80	489.79
1978–79	130.00	6.35	214.00	35.00	10.15	394.50	24.90	170.50	38.0	233.40	627.90
1980–81	145.00	6.66	253.00	43.50	12.60	460.76	25.86	178.22	39.2	243.28	704.04
1983–84	178.00	8.65	329.00	62.40	20.00	598.26	25.50	175.00	39.5	240.00	836.50
1985–86	200.00	10.00	380.00	75.00	25.00	690.00	25.00	170.00	40.0	235.00	925.00

Source : **Associated Chambers of Commerce and Industry of India, 1974.**

As no clear understanding of the nature and components of demand for electric power exists, capacity additions and pricing of power are usually done in an ad hoc manner. The new techniques of systems analysis and operations research are capable of optimising the entire power system. Unfortunately, these techniques are not being used extensively. In this context, the wide gap between our plan targets and achievements in creating capacity for power production needs immediate attention.

Most of the power stations in India work at a plant factor of only 35% because of maintenance problems and lack of rationalised load despatching systems. If transmission losses are added to this, the net efficiency of our electric power systems would be very low.

The current methods of cost-benefit analysis are somewhat inadequate to evaluate power system alternatives. These methods take into account only monetary costs and benefits and not social costs and benefits. Moreover, questions like who pays and who benefits are not satisfactorily answered by cost-benefit analysis. Current pricing policy of electricity undertakings, largely based on accounting data, does not reflect social priorities for the use of energy. For example, unless the income level of the beneficiary is equal to the income level of a person who incurs the cost, the benefit of Re. 1/- is very different from cost of Re. 1/-. The overall social cost-benefit analysis will not take care of this problem. Also, these techniques do not measure risk adequately. However, these questions are potentially loaded with political decisions which cannot be answered by a purely economic analysis. The political questions are essentially those of choice of values and goals which can be determined in our country only through democratic processes.

In planning, we can distinguish between two criteria : economic and energistic. The former expresses the value that society places on a product or action. The latter measures what is commodity which is the ultimate limitation—energy. The two valuations, approach each other asymptotically, meeting at some distant point of time. For the ultimate long range planner, economic and thermodynamic analyses are equivalent. In fact, thermodynamic analysis serves to estimate the minimum energy needed to effect a transformation when it happens imperceptibly slowly. In real life we cannot be that slow and therefore, must expend the additional energy to effect a transformation quickly. Fast travel, mass production, quicker consumption—all involve such higher consumption of energy. So far in history, since energy has not been properly priced, more and more of energy has been spent to achieve things of doubtful value. The concorde and the electric toothbrush strike my mind as examples. A time has come to pause and undertake an energistic analysis of our technologies in terms of our real needs.

Energy analysis leads us to evaluate the alternative uses of energy which are not always reflected by its pricing. Economic analysis largely assesses the cost rather than the value. If we use energy analysis for the long term perspective, it leads us to important conclusions about population, land use and consumption patterns.

Ours is a world with finite resources. The exponentially increasing use of fuels cannot go on for ever. In a study using dynamic modelling, a team of scientists from the MIT analysed the relationship among food production, energy production, population, natural resources, industrial production and pollution. Their results have been given wide publicity in the book "Limits to Growth". It concludes that such increasing use of fuels cannot go on for ever. Possibly, the world will be depleted of them within a period ranging from 50 to 100 years. Hence there is a great urgency for conservation of our resources and developing alternative technologies to produce energy from renewable resources. Solar energy and fusion technology appear to hold such unlimited promise.

Development of New Technologies

SINCE losses due to the use of low quality coal and poor transmission of power are very high, R&D programmes have to be initiated to solve this problem as soon as possible. Research also needs to be done in improving conversion efficiency and thermal exchange of different types of generating plants. Many of our electric appliances are very inefficient in the use of power. These have to be redesigned so that they use power more efficiently. Fuel efficiency in many of our industrial enterprises can also be improved significantly by redesigning industrial equipment like boilers. We also need to develop technologies which are more labour-intensive. I had already mentioned environmental aspects of energy earlier. In some areas there is a clear need to develop control and monitoring equipment to ensure environmental quality and safety.

The development of solar energy and fusion technology are crucial and probably this will be the dominent form of energy in the next century. Large scale generation of solar power presently requires enormous amount of land and new storage techniques, but it has a huge potential in rural areas in conversion of agricultural waste into fertiliser and fuel, storage and drying of grains and fodder and growth of fuel plantations. In urban areas it has great potential for domestic heating and lighting purposes and desalination. While the short term measures redistribute the use of energy, the long term solutions really depend on development of new technologies. Here I would like to stress on the following areas which appear to hold maximum potential.

As our coal resources are most important, we have to generate energy in the near future to a very large extent from this resource. As most of our coal is of poor quality with high ash and sulphur content, the need to develop economic refinement methods is vital. Such refinement reduces transportation cost also. Coal liquefaction and coal gasification will also be very important

Solutions to Energy Crisis On National Basis

ling.

Our oil and gas resources are very limited and hence there is a need to develop a substitute for oil as fuel. It is possible to shift to coal for supplying process heat in many industries with currently available technology. Substitution of oil as a raw material for fertilizer production would prove to be a more difficult task especially with some of the existing plants. Development of organic fertilizers and biological nutrients and pest control methods appear to be possible solutions. Even more difficult would be the substitution of oil as a raw material for the plastics and chemicals industry. Substitution of oil as fuel for aviation and road transport would not be possible in the near future.

As our uranium resources are limited, the need for developing breeder technology, which can make use of our uranium resources far more efficiently, is very high. Introduction of the breeder technology will enable us to make use of our poor quality uranium ores.

The potentialities for geothermal, wind and tidal energy appear to be limited and localised in India. A few coastal areas and hilly terrains have possibilities of generating some power from these sources purely for local and intermittent applications. Hence no large scale application of resources or exploration may be feasible in these fields in the near future.

Transportation uses a large amount of fuel. The experience of developed countries shows that the individually owned automobiles cause not only energy crisis but also pollution, transportation bottlenecks, higher accident rates etc. Though in our country this is not a major problem yet, we need to develop mass transportation technology in a big way and restrict individual transport media like cars, scooters and the like. In some areas of our large metropolitan cities, this is a necessity even today. Increased dieselisation of tracks will have to be viewed in the context of the relative efficiencies of coal and oil. Electrification might be a better solution while intra-city transportation can perhaps be through buses and trucks. In this connection, it is useful to recall that the current bottleneck in wagon shortage is mainly caused because 30% of the coal carried by the railways is for their own consumption. If the tracks are electrified, this capacity will be released for the carriage of other goods.

There is a great potential in non-commercial fuels like vegetable wastes, firewood, and animal wastes. The cowdung that will be available in India in 1975-76 has been estimated around 324 million tonnes. In 1972 we had used only .15 million tonnes of cowdung in gobar gas plants located in various areas to produce methane gas and manure. These plants have been set up with the assistance of Khadi and Village Industries Commission. The designs for these plants have been standardised long ago and they have a very high potential for satisfying local energy and fertiliser needs of rural areas. As this material is available in very large quantities, there is a potential for setting up one plant in each big-sized village. Unfortunately, this programme has received lukewarm attention so far. With adequate standardisation for more operational efficiency, follow-up and maintenance and publicity/education, these plants would prove to be of great value to many of the rural areas.

In urban areas, the potential for generating energy from urban wastes which largely contain garbage, is very high. Through incineration or wet oxidation, considerable amount of heat can be recovered and gas generated. The manurial properties of the urban wastes are also very high, which could be useful in agricultural activities. Presently, a large amount of urban wastes is untreated and discharged into the surrounding environment thus resulting in pollution and health hazards. The gas from urban wastes can also be used as an industrial fuel or for domestic gas supply.

Vegetable waste can be used to produce materials like bagasse. While considerable deforestation has gone on in the past few years to secure firewood and industrial wood, R&D on quick growing trees has been neglected. The use of wood as a fuel in rural areas and to some extent in urban areas would continue for a long time to come. Hence, considerable efforts have to go into quick afforestation.

Problems in Power Development

WE recognise that electricity will be a major form of energy in the future. Electricity is clean, efficient and easy to handle. While an all-electric economy would be a long way off, electricity for domestic and industrial purposes will continue to be used more and more. Larger and larger power stations are being set up all over the world. Stations of 2,000 MWe capacity in single units are being designed. In our country we are now planning 500 MWe capacity individual units. Construction of such stations poses problems like adequacy of cooling water, ruling out many inland sites, acceptable thermal and other pollution criteria for different sites, land use policy, integration with existing communication and transport systems, future technology developments, the size of an individual unit vis-a-vis the size of the grid, the nature of the power system, the acceptable safety limits and engineering, manufacture and transportation of large-sized high precision equipment, particularly for nuclear power plants.

Energy Organisations

WE had earlier identified that considerable fragmentation exists among the organisations we have for development, generation, distribution and consumption of energy. Research and development for energy is carried on largely by various R&D laboratories under the central ministries. Planning for energy is being undertaken by the

...Will Have To Be ...for Long Time'

Central Water and Power Commission. The regulatory authority for electricity rests with the Central Electricity Authority. The production of coal is undertaken by the Coal Mines Authority, National Coal Development Corporation and the Bharat Coking Coal Ltd. Exploration is being done by the Geological Survey of India and the Mineral Exploration Corporation of India. The ONGC explores for on and offshore oil. The railways carry the coal to consuming centres. The state electricity boards construct and operate power stations. There are some municipal corporations which are also responsible for electricity generation and distribution in addition to private companies. There is no single body which is responsible for co-ordination among these various agencies. The state of efficiency of these various agencies is to well-known to be recounted here. Presently, a super "Energy Board" is being contemplated to plan and co-ordinate the energy policy of the country. In the atomic energy programme, we have approached the problem differently. Horizontal and vertical integration, right from the R&D and exploration of atomic minerals, mining and production of fuel, manufacture of heavy water to design, construction and operation of nuclear power stations have been achieved under the umbrella of the Atomic Energy Commission. Communication among the various units and continuous interaction are very effective so that work flows fairly smoothly.

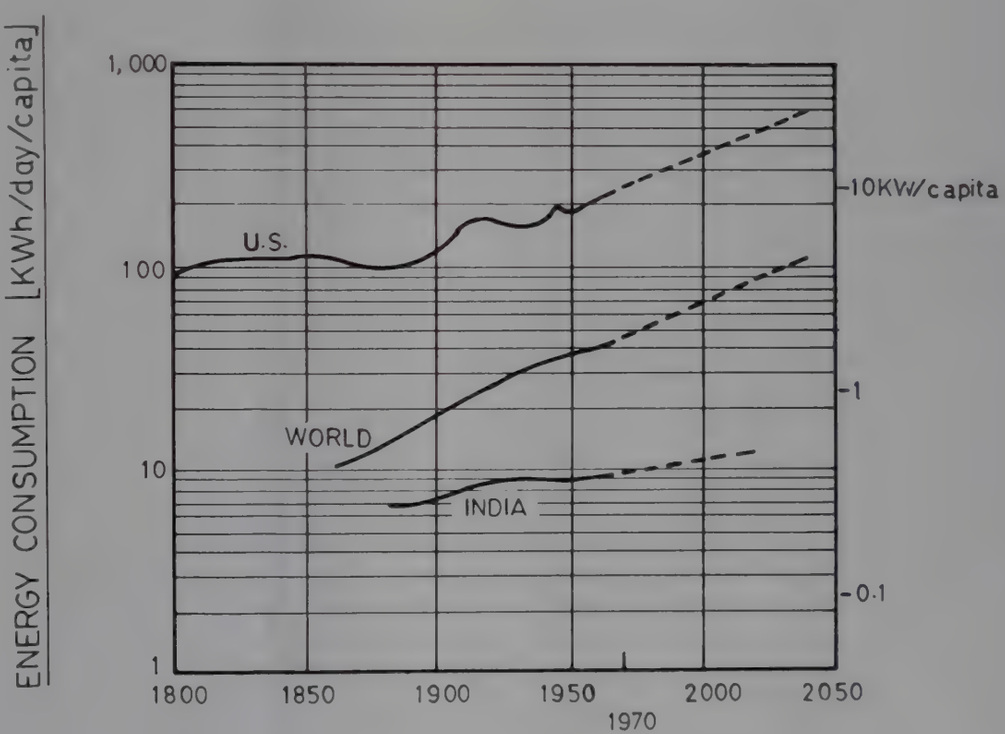
Training and development in these energy organisations has been a sadly neglected function. Without continuous upgrading of skills, increase in productivity would be negligible. Industrial relations is again another area which has been grossly neglected.

The present-day electricity systems are so complex that they need powerful computers for data processing and control of load despatch etc. The progress of many of our boards in this regard has been abysmally poor with the result that most of the systems are being sub-optimally used.

Energy Development in the International Scene

I have surveyed briefly the energy scene in India today. While energy crisis is truly a global phenomenon, its solutions will continue to be national in a very large measure for a long time to come. International solutions to the energy problems are still very few in number. Joint R&D projects, international transfer of technology, sharing of resources on a barter basis, and perhaps transportation of energy across national frontiers are some of the possibilities in the future. International government aid programmes could be of assistance in this process. I was gratified to learn that recently an international energy bank has been set up in London to finance and promote energy projects in different parts of the world. I, for one, believe in self-sufficiency in energy development but self-sufficiency is a continuing process and selective inputs from outside can catolyse and speed up the process of technological independence. Self-reliance in critical areas such as fuel supply is very vital. I had mentioned earlier about the finiteness of the world's fuel resources and their unequal distribution among nations. The investment necessary in developing advanced energy generation and distribution technologies is rather high. All these factors point out to the need for greater collaboration in the international energy context. Inspite of political alignments and power struggle between nations, I do hope that under the auspices of the

GROWTH IN ENERGY DEMAND



SOURCE : SCIENTIFIC AMERICAN, SEPT.,1971

United Nations, development of energy for the people of the world can take place in a transnational framework.

In India, we are, to some extent, dependent on other countries for the supply of fuels like oil and enriched uranium, for technologies of electric power generation and transmission and industrial energy uses. On the other hand our know-how and capabilities in the design and construction of power stations and supply of critical components in energy use could be of great help to many developing countries in Africa, West Asia and South East Asia. Our technical consultancy organisations have also made a modest beginning in helping other countries in their power development programmes.

Strategies for Energy Development

I would like to offer some suggestions in solving the energy crisis and promoting a meaningful energy programme for the future.

In the short phase (till 1980), the supply of oil and gas will certainly be restricted and their prices will continue to be high. Thus, measures for conserving oil for the petro-chemical and fertilizer industries would be essential. There will therefore be need to find substitutes for oil used for other purposes. The latter will mean the conversion of many of our industrial furnaces to coal base, restricting the dieselisation programme, development of coal-based fertilizer technology and of alternative domestic fuel for lighting and cooking and limiting the use of cars coupled with an increase in the means of mass transportation. These objectives can be achieved by a number of instruments like fiscal policy, pricing policy, rationing and stoppage of certain activities which are oil-intensive and which do not fall within the priority sector. Product mix of refineries will also have to be changed to maximise the output of high value fractions.

Besides intensification of oil exploration, the remedial action would involve increase in coal productivity and efficiency of its transportation, encouragement of the use of coal as a substitute for fuel oil etc.

The measures to conserve energy need not be detailed here, for they are well-known and have been implemented in times of shortage already. These restrictions should be continued and accepted as normal.

Something may be said about measures to increase production of energy and its better use though, to a large extent, these too need no emphasis as they are already well-known. These steps could include optimisation of energy generation and distribution systems by using operations research and computers, better training of personnel and maintenance of equipment, a rigorous estimation of sectoral demand for energy so that allocation and price could be in accordance with the priority of activities, reduction of construction time, and cost of power stations to name a few. A large portion of these tasks can be carried out by a national energy authority which could plan, finance, co-ordinate and regulate energy generation, distribution and utilization.

Use of urban wastes for generation of power and as fertilizers, evolving fast-growing trees in semi-arid soil conditions for use as fuel, and expansion of gobar gas plants to serve rural needs may also be considered to supplement the other energy sources.

In the intermediate phase, that is during 1980-1995, we should have commercially operating fast breeder reactors and large sized power stations with single units of anywhere between 500 to 1,000 MWe along with a national grid interlinking these large stations on an inter-regional basis. There would be very large centralized generating stations to meet an ever-increasing demand for electrical energy, compared to other forms of energy. There will also be a need for better methods of transporting energy, such as ultra high voltage lines, super-conductive cables and hydrogen pipelines.

In the long term phase, that is beyond 1995, with the increase in energy demand, there will obviously be need for finding new sources. Fossil fuels may be expected to be less important or viable and therefore the new sources will have to be essentially renewable. These sources could be solar power and fusion. Geothermal energy and thorium breeders would continue to be improved during this phase, though any new breakthrough is unlikely in these areas.

Under these new circumstances there will be an enhanced understanding of the relationship between energy and the total environment, and energy planning and use would be achieved more systematically, reflecting social priorities better than is the case now.

Towards a New Energy Policy

I have made an attempt here to suggest a framework to understand the role of energy in our civilisation and the need for a more rational energy policy. Our understanding in this regard is rather poor now. I am hopeful that through more intensive research we would be able to develop technologies which can solve all our energy problems. We also have potential management capabilities to create energy systems and organizations which can manage energy more effectively. We need today a great deal of more work to be done through education, publicity, etc. to generate more informed values about the priorities in the use of energy and an understanding about the role of energy in human civilisation. ●

NUCLEAR INDIA

is a monthly publication of the Department of Atomic Energy, published around the 20th of each month. To ensure prompt attention, all communications should be addressed to the Editor, NUCLEAR INDIA, Department of Atomic Energy, Chhatrapati Shivaji Maharaj Marg, Bombay 400 039. While intimating change of address, the code and number given on the wrapper should be mentioned. Bombay recipients may contact 250477 for prompt action.

High Yielding Jute Mutants Undergoing Trials; Garlic Oil as Insecticide

AT the Bhabha Atomic Research Centre's Biology and Agriculture Division, TG-1, a bold seeded table variety of groundnut which is suitable for export, was released for cultivation by the Central Varietal Release Committee of the Ministry of Food and Agriculture. The Committee also recommended Variety TG-3 for trials at the district level. A new selection (14-4) showed further improvement in yield over TG-3. Seeds of TG-1, TG-3 and S-14-4 have been supplied to the Vanaspati Manufacturers Association, Bombay for testing them at the cultivators' fields under their extension programme.

The Centre has also evolved high yielding jute mutants which have been included in multi-locational trials conducted by the Indian Jute Industries Research Association (IJIRA) in Assam, Bengal and Orissa. A few promising mutants of Hibiscus (mesta) were also given to IJIRA for evaluation at Purnea and Krishnagar.

Insecticidal properties of the vapours of garlic oil, both natural and synthetic, has been established against a wide variety of insect pests. The toxic action on insects is not due to failure of their respiratory metabolism but is associated with the impairment of nervous activity. This is due to imbalance in the levels of acetylcholine and its enzyme involved in synoptic transmission.

In the field of **radiation preservation of foods,** optimal irradiation conditions for extending the shelf-life of various flesh foods, grains, fruits and tubers have been worked out. Food compositional changes, nutritional evaluations and the effects on additives and associated food flavours, pathogens and toxins have been investigated.

Optimal conditions for preparing fish protein concentrates from Bombay duck and shark muscle have been worked out and studies on their properties are being carried on. Successful processes for defatting peanuts and soyabeans and preparing quick-cooking dehydrated peas have been developed. Rot-proofing of jute fibres with vinyl monomers has been standardised.

Four Heavy Water Plants for Current Nuclear Programme

FOUR Heavy Water plants are being erected at Kota, Baroda, Tuticorin and Talcher to produce about 500 tonnes of Heavy Water for use in nuclear power plants in the country.

The Baroda plant is scheduled to be ready for commissioning by June 1974.

Erection of plant and machinery and equipment in the Kota and Tuticorin plants is expected to commence shortly. The Tuticorin plant is expected to be ready for commissioning by the middle of 1975, and the Kota plant by early 1976. In respect of the Talcher project, the civil engineering works will commence shortly and are expected to be completed by the end of 1974. Erection of plant and equipment will commence by October/November 1974. The plant is expected to be ready for commissioning by mid-1976.

Radiation Protection Service Covers 32,000 Workers

THE countrywide personnel monitoring service for evaluating radiation exposures covered about 32,000 radiation workers from 1,975 institutions during the calendar year 1973. The corresponding figures for the previous year are 28,000 and 1,775 respectively.

Countrywide radiological protection surveys were conducted in 250 institutions consisting of 123 medical, 71 industrial and 28 agricultural and research institutions.

The Radiation Medicine Centre Improves Facilities for Medical Applications of Radioisotopes

THE Radiation Medicine Centre of the Bhabha Atomic Research Centre, and the Tata Memorial Centre in Bombay are involved in the area of nuclear medicine. The RMC has now completed ten years. During this period it has provided facilities for diagnostic, investigative and therapeutic uses of radioisotopes on about 20,000 patients. The RMC enjoys the status of a Regional Reference Centre for Nuclear Medicine in South East Asia for the World Health Organization, in collaboration with the International Atomic Energy Agency.

The Tata Memorial Centre includes the Tata Memorial Hospital. The TMC undertakes research studies in cancer, besides diagnosis and treatment of this condition.

Basic research studies involving both human and animal cancer experiments were continued in the Centre during the year. Investigations on breast cancer, including the ultrastructure studies of milk tissue specimens and various hormonal factors were continued. Immunological studies were carried out on oral cancer, osteogenic sarcoma and chronic myeloid leukaemia. The programme of biological and biochemical screening of human tumours was actively pursued and experimental studies on the aetiology, pathogenesis and basic behaviour patterns in abnormal and malignant oral mucosa are in progress. Testing of known environmental carcinogens specific to our country, *viz.* tobacco, betal quid, edible oils etc. are being pursued.

It is planned to have combined units of clinicians of the Hospital and research scientists at the Cancer Research Institute to explore more intensive and multidisciplinary approaches to the study of cancer. International collaboration is being planned for protocol design in end-result reporting and also to conduct specialised endocrine estimations in high and low risk breast cancer patients. ●

Electronics Corporation Emerges as Trend-Setter

THE Electronics Corporation of India Ltd. (ECIL) has emerged as a trend-setter among the public sector units.

Shri A. S. Rao, the Managing Director of the Corporation detailed some of the highlights of ECIL's activities and achievements at a press conference on April 10, at Hyderabad.

During 1973-74, the corporation maintained its rate of growth and expanded its activities by more than 75 per cent in production, and over 80 per cent in sales, over the levels achieved during 1972-73. In terms of value, the production achieved is of the order of Rs. 1,157 lakhs, and sales Rs. 1,057 lakhs as against the previous year's figures of 657 lakhs, and 577 lakhs respectively. It has earned during the year a net profit before tax of 140 lakhs, compared to Rs. 113 lakhs of the previous year. The Corporation has continued to diversify its product range to meet the requirements of nuclear power plants, the Railways, the Defence services, communications and applications in medicine, laboratories and educational institutions.

Two major areas where the Corporation has done significant work are computers and TV. The Corporation has successfully marketed during the year the third generation computer **viz.** the TDC-312 and TDC-16, incorporating therein an integrated circuit technology, thus giving a further fillip to the indigenous computer manufacturing capability. R & D effort is on to develop a more powerful computer, TDC-32. The Corporation has built up the necessary base for its software applications, engineering and after sales service functions.

In TV, the ECIL has made a major breakthrough in the designing, fabrication and marketing of receivers. The Corporation has sold more than 12,000 TV sets during the year in the Bombay and Poona markets. The Corporation plans to reach its licenced capacity of 20,000 sets per annum during the current financial year, and to extend its selling activities to other areas like Madras and Delhi. To further increase the production of TV sets in the country, it has made a beginning by providing the knowhow to the Kerala State Electronics Development Corporation for the manufacture of 5,000 sets per annum without charging any royalty. There are also plans to bring out a portable TV receiver set which will be well within the reach of the common man. The Corporation is already manufacturing closed circuit TV systems, and is supplying battery-operated community TV sets and accessories needed for the satellite instructional television experiment programme of the Indian Space Research Organisation.

Besides continuing to meet the needs for antenna systems, microwave products and sophisticated professional grade precision components of the various ministries and the electronics industry in the country, ECIL has for the first time in the country introduced ultra sonic flaw detectors, lithiumdrift silicon detectors for use in nucle power reactors, auto diodes for the a tomobile industry, glass-to-metal sea for the refrigeration industry, tantalu capacitors, synchros and gyros for Def nce, metal film resistors and surm potentiometers for general industrial us

It plans to take up work in las technology, particularly the manufa ture of the laser photocoagulator. Th instrument helps in the repair detached retina.

Besides contributing to import subst tution, the Corporation is also makir efforts in the export market. It ha made a small beginning by executir an export order for 1.6 lakh pieces moulded metal film resistors to th USA. A preliminary survey made b ECIL reveals that there is a good poter tial market for its products outside.

Indian Experiment in Skylab III

THE Tata Institute of Fundamental Research, Bombay, the Physical Research Laboratory, Ahmedabad, and the University of California, Berkeley were participants in a jointly designed cosmic ray experiment conducted in SKYLAB III. The experiment involved the exposure of an assembly of Lexan polycarbonate dielectric detectors during the SKYLAB mission.

The objective of the experiment was to study in detail several components of corpuscular radiation in space, both of solar and galactic origin, which are of low intensities and hence are not accessible for studies in balloon and rocket experiments. The SKYLAB provided a special opportunity for studying these components. Dielectric detectors were used because they are capable of withstanding the thermal and the radiation environment of free space for a prolonged period of time, *i.e.* for several months, without any significant loss of their sensitivities.

SKYLAB III was launched by the National Aeronautics & Space Administration in the middle of November 1973 with a crew of three astronauts : Col. Gerald Carr, Commander; Dr. Edward Gibson, Science Pilot; and Col. Willia Pogue, Pilot. Carr and Gibson deploye the detector outside SKYLAB durin their first space walk in the third wee of November 1973. At the conclusio of the SKYLAB mission, the detecto was retrieved by the astronauts an returned to the earth in early Februar 1974.

The part of the detector assigned t Indian experimenters arrived in Indi in March 1974. This detector had a exposure of 72 days in free space with negligible amount of shielding materia This is the longest free space exposur of an experimental detector which ha been brought back to earth, and th first successful satellite experiment b researchers in India. The detector i expected to yield new and valuabl information on particle radiation in fre space, both of galactic and solar origin as well as on the micrometeorites.

The study of the exposed detecto is being made jointly by the researc groups of Prof. S. Biswas of the Tat Institute, Prof. D. Lal, Director, Physi cal Research Laboratory, and Prof P. B. Price of the University of Cali fornia, Berkeley, USA.

Edited and published by Jagannath Sharma, Publications Officer, Dept. of Atomic Energy, Government of India. Chhatrapati Shivaji Maharaj Marg Bombay 400 039, and printed by him at Printwell, Mahalaxmi, Bombay 400 011.

Registered No. R. N. 9002/62

NUCLEAR INDIA

VOL. 12. NO. 12 PUBLISHED BY THE DEPARTMENT OF ATOMIC ENERGY AUGUST 1974

ECIL Vindicates High Quality of Indian Technology

By A. S. RAO

Managing Director, Electronics Corporation of India Ltd.

THROUGH more than seven years of successful operation, the Electronics Corporation of India Ltd. (ECIL), has vindicated the cause of its coming into being, namely to establish the efficacy of indigenous technology for industrial utilisation. The Corporation has grown rapidly, largely because of its innovative culture and remarkable productivity. In 1973-74 its sales reached Rs. 11.5 crores. For the second year in succession it is paying a dividend on equity; the latest dividend being 6.5 per cent. During these seven years, its per capita production has risen nearly ten-fold, from approximately Rs. 3,200 to the present figure of Rs. 32,000, of which more than 50 per cent is value added at ECIL.

The year 1971-72 was important to ECIL because profits earned during that period more than covered the net cumulative deficit arising from development and pre-production expenditure. The next year was notable for the fact that ECIL paid its maiden dividend of 5 per cent.

During the last three years, sales from ECIL have grown at approximately 80 per cent per year, still leaving an average growth rate since inception of above 100 per cent. The aggregate sales since inception have been Rs. 24 crores, of which nearly Rs. 21 crores came in the last three years. As a result, ECIL has been able to achieve a net foreign exchange saving of Rs. 15 crores, a net yield of 3:1 from foreign exchange made available to it.

See pages 4-5. "Development of Nuclear Energy in India: 1947-73" by Dr. R. Ramanna

The Corporation has drawn up an expansion plan that coincides with the Fifth Five-Year Plan. In 1974-75, the first year of this plan, ECIL'S target is Rs. 20 crores each in production and sales. This target represents a growth of 70 per cent over the achievement in 1973-74. By 1978-79, the terminal year of this plan, ECIL would have trebled the volume of its production and sales, the target being Rs. 60 crores each and the number of employees going upto 15,000.

Composed of 11 divisions, during 1973-74, ECIL had on its rolls nearly

(Continued on page 2)

170 Nuclear Engineers and Scientists Pass Out of Trombay Training School

ONE hundred and seventy graduate engineers and scientists passed out of the 17th one-year training course of the Bhabha Atomic Research Centre's Training School at Trombay. These young men and women will be taking up positions in the various institutions and projects of the Department of Atomic Energy.

The Chief Guest at the Graduation Function of the Course, held at BARC on August 2, 1974, was Shri P. N. Haksar, Member, Atomic Energy Commission. Addressing the trainees and the large gathering of scientists and technologists, Shri Haksar urged them to understand and appreciate the historical forces which had helped evolve the country's social, political and scientific traditions and institutions.

Comparing the conditions under which advanced countries like Britain, the United States and Russia had developed, as also the progress made by China, Shri Haksar lamented the thinking in terms of copying or working on borrowed models for building up national institutions and traditions. Placing the development and growth of some of these advanced nations in perspective, he emphasised that every nation has social, political and historical conditions peculiar to it which demand a pattern of development best suited to the genius of its people and its particular needs. Shri Haksar asked the graduates to understand the historical context of India's growth and invest their intellectual resources for its development.

Speaking about the relevance of scientific institutions like BARC in India, he stressed that without such institutions, the country's centuries of backwardness could not be overcome. "We missed the first industrial revolution, so we cannot afford to miss the second industrial revolution, and that is my answer to all those who squeal about the nuclear experiment, about its peaceful purposes. The basic thing is : this country will not allow itself to be cheated out of the second industrial, scientific, and technological revolution. We shall then become slaves

(Continued on page 2)

ECIL Will Make Country Self-reliant in Computer

(Continued from page 1)

4,200 employees, of which about 800 were higher paid staff on whom the responsibility for generating new technology has rested. The average age of ECIL employees is around 27.

Among the high points of ECIL's achievements during 1971-72 is the supply of the complete control instrumentation system for the Rajasthan Atomic Power Project. This work, demanding the use of very advanced technology, has contributed greatly to the increased confidence in the industry in the ability of the Indian technologist. The need for self-reliance, not merely out of choice but also out of inevitable necessity, is great, and the significance of ECIL's technological potential in the field of power reactor control instrumentation is obvious. It may soon be possible to meet the entire instrumentation needs of the planned atomic power projects. The foundation for technological innovation that is now firmly established at ECIL can be built upon to yield instrumentation systems of high complexity and precision as required by diverse industrial techniques and processes.

Another highlight of ECIL's activities is the Closed Circuit TV (CCTV). A 32-camera, 32-monitor CCTV system, valued at approximately Rs. 35 lakhs was delivered by ECIL to the Security Press at Dewas sometime back. CCTV is a vital tool that can have a broad range of applications. The Corporation has the turn-key capability to survey the customer's requirements and build CCTV networks to suit his particular application.

The emergence of a distinct line of bio-medical electronic instruments at ECIL is another important development in the last three years. Included in this line is the battery-operated, ambulance-mounted ICCU (Intensive Cardiac Care Unit) that can strengthen rural medical services operated from district or tehsil headquarters. Availability of such a unit within the first half-hour of a heart attack is of vital importance. This time is otherwise spent in moving the stricken patient to emergency medical care, which may be more than half-hour away from the typical village. The unit is now undergoing final product engineering checks prior to field trials.

A major portion of ECIL's growth hereafter is expected to come through computers. The TDC-12 computer, originally developed at the Bhabha Atomic Research Centre (BARC) has now graduated at the ECIL to an advanced third generation version known as the TDC-312. EDP systems featuring TDC-312 as a Central Processing Unit (CPU) and interfaced with appropriate peripheral units have now moved into the market. More than 40 ECIL-made computer systems are now in operation, meeting applications ranging from industrial process control to locating centres of seismic disturbances. The TDC-316, again using ICs and of larger word-length than the simpler TDC-12 and TDC-312, has also started entering the market, widening the range of ECIL CPUs and total computer systems. The value of production of computers at ECIL has exceeded the aggregate figure of Rs. 4 crores, most of which came in the last three years.

The TDC-332, a large computer comparable to some of the most advanced computers today, is expected to be working before the end of 1975-76 and entering the market the following year. Its capability is such that it can meet applications of a standard that one normally expects to fill only through import of large sophisticated computers. With the development of TDC-332, India will have established a full-fledged computer line that can eliminate further import. It will also mean that in this area of strategic significance, both to defence and to general industry, the country would be entirely self-reliant. In all, 830 computers, valued at Rs. 65 crores, are expected to be sold by ECIL during the five-year period, meeting almost the entire demand of the country likely to arise then.

The work at ECIL on the building of large and medium size antenna systems, begun some two years ago, will expand, taking the volume of production to about Rs. 10 crores by the end of the Fifth Five-Year Plan. Included in the range is a large antenna for a satellite earth station, medium-size antennas for the P & T, and

Training Programme An Important BARC Activity

(Continued from page 1)

once again and nowhere is it guaranteed that our independence is sacrosanct."

Shri Haksar was welcomed to the function by Dr. R. Ramanna, Director of the Bhabha Atomic Research Centre. Describing the training programme of BARC as one of the most important activities of the Centre, Dr. Ramanna stressed that the School was there not merely to provide information to the trainees but also to prepare them as leaders for the new nuclear projects that were envisaged.

The Chairman of the Atomic Energy Commission, Shri H. N. Sethna, exhorted the graduates to put in their best to see to what extent the country's problems could be overcome. The kind of leader the BARC Training School was preparing was one who would be willing to accept blame when things went awry, and who would be large-hearted enough to share credit when things went well, he said. Welcoming the graduates to the atomic energy family, he visualised a long and fruitful association and a positive contribution from all of them in the nation's developmental effort. ●

10-foot chicken-mesh antennas for rural community receivers.

An important feature of ECIL's activity next year is the Satellite Instructional Television project. ECIL'S Microwave Division is making the front-end converter for this project, while its Television Division is handling the remaining portion of the receiver. The Antenna Systems Division is making the chicken-mesh antenna, while the integration of the above systems is being carried out jointly by all these divisions of ECIL in close coordination with the Indian Space Research Organisation. Experimenial telecasts are scheduled for mid-1975.

On the components side, the supply of defence-grade tantalum capacitors and mechanical and other components by ECIL has been of particular importance to defence production.

Expansion in this area includes a four-fold growth in the output of semiconductor components, 300 per cent growth on tantalum capacitors, both through diversification of product range, and the introduction of new products such as nickel cadmium cells and silicon controlled rectifiers. A new product, the 2-axis rate gyro, is also being introduced in 1974-75.

ECIL'S practice of engaging in joint development work with government laboratories and research institutions such as the Central Electronics Engineering Research Institute, Pilani, the National Physical Laboratory, Delhi, and the Electronics and Radar Development Establishment of the Defence Ministry (LRDE) at Bangalore, as also with the Bhabha Atomic Research Centre, will continue on an increasing scale. The problems relating to imports, such as shortage of foreign exchange, etc. are also factors which may aid the growth of indigenous effort, and as the scale of such effort expands, the research laboratories will take on a bigger role in developing industrial know-how for immediate utilisation. ●

Prof. O. Siddiqui of the Tata Institute examines an exhibit at an Interschool Science Exhibition.

Science Education Looks Ahead

By V. G. KULKARNI

Homi Bhabha Centre for Science Education.

SCIENTISTS are actively participating in education. An acutely felt sense of social responsibility has led many of the younger scientists in the country to sacrifice even lucrative careers to contribute towards innovation in education.

In 1968, scientists from the Tata Institute of Fundamental Research, and school teachers in Bombay discussed the need to provide channels for the creative enterprise of school children, and the need to induce in them a sense of deep involvement in the study of science. The first step taken was to hold an exhibition of scientific exhibits conceived and built by the students, to provide them wide scope for displaying curiosity, creativity and technical skill as also to make an impact on the public. The Bombay Association for Science Education (BASE) was founded three years ago as a result of this interaction.

Started in 1970, these exhibitions are now an annual feature. The Sir Dorabji Tata Trust provided the seed money for the first year. Very soon the number of schools participating in the exhibitions, as well as the number of exhibits, increased rapidly. Public enthusiasm has been overwhelming. The exhibitions are now almost self-supporting and one can say with confidence that they have now found a permanent place in the cultural life of the city. Perhaps what is more heartening is the number of municipal schools participating in this programme, and the sizeable proportion of prizes carried away by the municipal school children.

The activity has also made an impact outside the city of Bombay. A number of prize-winning entries have been selected every year for the National Science Exhibitions held in Delhi.

Another important activity of the BASE which has met with great success is its programme of lecture-demonstrations held at the TIFR. In these lectures, a scientist selects a topic within the intellectual reach of school children, and explains the basic concepts with simple experiments. The response of the schools and the students has been so overwhelming that the lecturers have had to repeat their talks the same day to accommodate more students. These lecture-demonstrations are now arranged more frequently, and in multiple languages.

(Continued on page 8)

Development of Nuc

By D
Director, Bhab

The atomic energy effort in India started period, India not only built up the basi energy, but also the industrial infrastruct delivered at the Nehru Memorial Museu the early days of the effort and the many scientists and engineers who built up th part of the address here. The remainin

"That the organisation of research in universities as it existed during the pre-war period was insufficient was realised by a group of scientists working during the war period. Amongst them were Dr. H. J. Bhabha and Dr. S. S. Bhatnagar. It was during these years that Dr. Bhatnagar dreamed of a chain of national laboratories in various disciplines all over India. At about the same time, Dr. Bhabha was planning a centre of excellence in nuclear science to come up in Bombay."

IN understanding the rapid development of the utilization of nuclear energy in India, it is useful to recall the organisation of science as it existed in India before Independence. Pre-war scientific developments in India were concentrated, not unexpectedly, in universities. The biggest impact of science in our universities came from the Calcutta University and owes its origin to its great Vice-Chancellor, Sir Asutosh Mukherjee. It was due to his inspiring organisational genius that the country can boast of Raman, Saha and others. However, the structure and organisation of those times was essentially for individual scientists to flourish. Research on a wider scale involving industry and team work just did not exist, and we may guess, was neither encouraged nor looked upon with favour. There was however one exception to this and that was the Indian Institute of Science at Bangalore. But even here, the time was not ripe for large scale technological research. It is, however, good to recall that it was in this Institute that the founder of the atomic energy programme in India, Dr. H. J. Bhabha, did much of his early thinking for a new science structure in the country.

That the organisation of research in universities as it existed during the pre-war period was insufficient was realised by a group of scientists working during the war period. Amongst them were Dr. H. J. Bhabha and Dr. S. S. Bhatnagar. It was during these years that Dr. Bhatnagar dreamed of the chain of national laboratories in various disciplines all over India. At about the same time, Dr. Bhabha was planning a centre of excellence in nuclear science to come up in Bombay. He was already aware of the possibilities of the energy contained in the atom and expressed it in his now famous letter to the then Chairman of Sir Dorabji Tata Trust in 1944 in connection with the establishment of TIFR :

> "When nuclear energy has been successfully applied for power production, in say, a couple of decades from now, India will not have to look abroad for its experts, but will find them ready at hand."

TATA INSTITUTE OF FUNDAMENTAL RESEARCH

Real development in nuclear science can be said to have started with the foundation of the Tata Institute of Fundamental Research with the funds provided by the Trustees of Sir Dorabji Tata Trust. Later, the Government of Maharashtra (then Govt. of Bombay) put in their contributions and finally the Central Government now provides nearly 99 per cent of its recurring budget. This Institute started off in a small wing in a flat in Peddar Road, mainly to provide the necessary facilities for Bhabha's own work in cosmic rays and theoretical physics. But with the coming of independence, he clearly saw that the TIFR could provide the base for a nuclear energy programme and he would have to expand the facilities of the Institute to include other branches of Physics, and disciplines such as Chemistry, Biology and Engineering. At his instance and with the help of S. S. Bhatnagar, the Atomic Energy Commission was formed in August 1948 with the following charter :

"The biggest impact of science in our universities came from the Calcutta University and owes its origin to its great Vice-Chancellor, Sir Asutosh Mukherjee. It was due to his inspiring organisational genius that the country can boast of Raman, Saha and others."

"(1) To take such steps as may be necessary from time to time to protect the interests of the country in connection with Atomic Energy by exercise of the powers conferred on the Government of India by the provisions of the Atomic Energy Act ;

(2) To survey the territories of the Indian Dominion for the location of useful minerals in connection with Atomic Energy ; and

(3) To promote research in their own laboratories and to subsidise such research in existing institutions and universities. Special steps will be taken to increase teaching and research facilities in nuclear physics in the Indian Universities."

As can be seen in the charter, first priority was given for the survey of natural resources, particularly materials of interest to the atomic energy programme such as Uranium, Thorium Beryllium, Graphite etc. A special unit with the original name of Rare Minerals Division was created at Delhi with the help of late Prof. Wadia. The next priority was given to the basic sciences, particularly Physics, Chemistry and Biology with the purpose of providing facilities and training of high quality research scientists. The eventual aim was to set up as early as possible a research reactor. It was realised that this by itself would not be sufficient for a nuclear programme unless there was simultaneously a programme for instrumentation, particularly in electronics. Dr. Bhabha clearly realised very early in the programme that no high quality research is possible without good instruments and the very

gy in India: 1947-73

A

h Centre.

ades back, around 1947-48. In this ersonnel for applications of nuclear ie nuclear programme. In this talk, July 29, 1974, Dr. Ramanna recalls ns and the triumphs of the pioneering ear capability. We are reproducing blished in the September issue.

Dr. Bhabha used to make a knowledgeable assessment and appreciation of each man's work and was able to bring them together so as to build up a truly cooperative spirit. It was in this way that a deep foundation was laid for multi-disciplinary cooperative work even as early as the fifties. The necessary spirit and tempo of research was kept up by inviting many distinguished scientists from abroad and India, and the Wednesday colloquia at TIFR were often great intellectual events. The names of Dirac, Pauli, Bohr come to my mind."

ct of their being produced in India was self progress. It is for this purpose hat a unit, called the Electronics Pro- uction Unit, was started in the TIFR. This production unit formed the nu- leus of the large corporation now in Hyderabad known as the Electronics Corporation of India Limited.

To give a feeling of the atmosphere it that time, I may be permitted to quote from my reminiscences. Con- sidering the number of people who have been recruited directly from various training centres abroad and some very enthusiastic good students from Indian Universities themselves, it is not easy to explain what it is that made all the people at that time, work in close teams and discuss their problems with one another with absolute freedom. This was certainly different from the atmos- phere that existed in other institutions and universities where the tendency was to work in separate compartments. It is possible that this was because of Dr. Bhabha's quick perception and understanding of various disciplines and by his talking to people in different sections at all levels. He used to make a knowledgeable assessment and ap- preciation of each man's work and was able to bring them together so as to build up a truly cooperative spirit. It was in this way that a deep founda- tion was laid for multi-disciplinary cooperative work even as early as the fifties. The necessary spirit and tempo of research was kept up by inviting many distinguished scientists from abroad and India and the Wednesday collo- quia at TIFR were often great intellec- tual events. The names of Dirac, Pauli, Bohr come to my mind.

While this foundation was being laid for a strong base in pure science and some work in electronics instrumenta- tion, there was a clamour all over the scientific circles in the country as to whether this was indeed leading us to one of the aims of the Commission: of setting up a small reactor. I recall Dr. S. S. Bhatnagar bemoaning to Dr. Bhabha in London in 1953 and his very words were "will I ever see a reactor in India before I die." Un- fortunately our first reactor came into operation in 1956 soon after the death of Dr. Bhatnagar (1955).

CHOICE OF REACTOR

In order to have a countrywide dis- cussion on our atomic energy pro- gramme, particularly about the choice of a reactor, its siting and the difficulties of setting up one indigenously, Pandit Nehru called a conference to which distinguished Indian scientists were invited. This was held in Delhi during the winter of 1954 at the National Physical Laboratory. We, who were heading various Divisions, were also asked to speak on our subject of spe- ciality. At this conference, I recall the presence of Prof. M. N. Saha, Prof. S. N. Bose, Dr. K. S. Krishnan and several other distinguished Physicists, Chemists, Engineers and Industria- lists from all parts of India. On that day, one could feel the tension in the air. The location of the Atomic Energy Establishment at Bombay was being questioned. The choice of the reactor type and the entire programme of developing our atomic energy mate- rials came under criticism. Pandit Nehru carefully listened to all the arguments, particularly to the various proposals on the type of reactor we should try and build by ourselves. With all our youthful enthusiasm we must have made an impression. Cer- tainly Dr. Bhabha had the entire discussion under control, but it was Prof. K. S. Krishnan, who was the last speaker, who clinched the argu- ment in his usual humorous style by quoting the story of Jacobi and his student. I quote it because the story made a big impression that day :

"...they did not expect us to make fuel elements of the required quality and thought we would eventually go to them for buying the fuel. Later, as it turned out, the fuel elements produced at Trombay were as good, if not even better, than the Canadian fuel elements. This event must be the first example in which our own technology established itself as being equal to that in the front rank of world technological developments."

"Yesterday, I mentioned the instance of a man, a young man, who had joined for research the great Mathe- matician Jacobi who was the brother of the great Orientalist. The young man had been with him for several months without having started any research work. When the teacher asked him about it he said : 'I have not yet read all the earlier literature on the subject'. Then the Professor turned to him and said, 'Dear man, if your father had waited to see all the girls before marrying one, where would you be? I would like you to make a start somewhere. You can get on with the scientific problems and proceed'. I would also say just the same thing. Because the subject involves so many different disci- plines, it needs cooperation from all quarters and a certain amount of sympathy is also necessary."

(Continued on page 6)

(Continued from page 4)

The Atomic Energy Programme Modernising Country's

This conference should be considered as one of the most important ones on atomic energy held in India as it consolidated the scientific opinion in the country in support of the steps taken by Dr. Bhabha towards the fulfilment of our programme. It was also quite clear that Pandit Nehru had given his full support to the programme publicly in front of all the scientists, some of whom had been very critical.

Due to Dr. Bhabha's close contacts with European scientists and his influence among the leaders of science in Europe, he was in constant touch with technological developments and possibilities abroad. He had managed to have an agreement of cooperation with France long before such agreements existed in this particular field outside the then nuclear countries. It was with the cooperation of France that we learnt a lot about reactor materials, reactor control, neutron physics etc. particularly with respect to natural uranium systems. But all this still had not put us in a position to build a reactor of our own. However, sometime in 1954, after one of his fairly frequent tours of Europe, Dr. Bhabha came back with a proposition that Sir John Cockroft had offered some enrished uranium fuel elements for building a Swimming Pool type reactor and that he had come to an agreement with him for the loan of this fuel.

All-round Enthusiasm

It was, however, to be a challenge in that we had to build the rest of the reactor, which included the civil engineering, design of the tank, and electronics control systems and prepare for its utilisation entirely by ourselves. It was also supposed to be built in competition with the Lido reactor at Harwell to see who would complete it first. I may add here that we went critical earlier by a few days. Since the whole project was a challenge, everybody seemed keyed up and it was one of those operations which was carried out with tremendous gusto. The reactor building was constructed in less than an year's time and because of this hurry it turned out that neither the roof nor the walls were leak proof against the monsoon. The Swimming Pool tank was also built in a record time and by August 1956 the reactor was actually ready for criticality trials ; the whole operation having lasted just one year. At the first trials in which Dr. Bhabha himself took part, it became difficult to try out various configurations of the uranium fuel in the water because the tank was still new and the water was not sufficiently transparent. Though we worked during the whole of the 2nd night, the reactor just would not go critical. This was because we had left a very big water gap in the centre not knowing enough about such neutron multiplying systems. This was realised on the 3rd day and the whole loading operation was reenacted on the 4th day, and on that 4th afternoon the reactor went critical. We could now claim that we had a critical reactor, the first in Asia, built entirely by ourselves except for the enriched uranium fuel. I also recall that within a few minutes after the reactor became critical, the Prime Minister, Pandit Jawaharlal Nehru was informed of it over the phone, even as the monsoon was flooding the whole place around us.

I have dealt in some detail about the *Apsara* criticality because it was the first to have psychological impact on the country for the development of modern technology. Though a lot of equipment for the reactor had been designed and made entirely by ourselves, there were still many people not willing to believe that we could establish a modern technology in the country by ourselves. The country seemed to be covered in a cloak of non self-reliance. People in general felt that every thing had to be imported from abroad, be it ideas or equipment. It seemed to many in India that nothing worthwhile was possible by ourselves.

We realised that to cash in on the success of *Apsara* we had to take a series of steps to make ourselves not only self-sufficient in quality but in quantity also. Even before the *Apsara* went into operation, the Indian Rare Earths Ltd. was producing Uranium and Thorium compounds of high purity. A decision was taken to build a Uranium Metal Plant immediately, and this turned out to be vital in our programme of self-sufficiency.

At the Geneva Conference in 1955, Dr. Bhabha played a very important role from the point of view of bringing about a discussion about both the importance of nuclear power for developing countries and of the possibilities of fusion. It was during this conference that a very generous offer from Canada was made to us of the gift under the Colombo Plan of a NRX type reactor, a natural uranium and heavy water system.

"The setting up of the Reprocessing Plant at the same time when CIRUS became critical caused some eyebrows to be raised, for it gave India clearly a nuclear option. At the opening ceremony of the Reprocessing Plant, Shri Lal Bahadur Shastri offered this Plant to countries of South East Asia for reprocessing their fuel in case this was required."

NRX Reactor

I recall the discussions which Dr. Bhabha had with all of us in Geneva in 1955 on the choice of the NRX type reactor for Trombay. While all of us including Dr. H. N. Sethna, Shri N. B. Prasad, Shri A. S. Rao and myself were keen on the NRX type reactor because it was a natural uranium-heavy water system and therefore a type which in principle we could fuel ourselves, for some reasons, Dr. Bhabha seemed to favour the Dido reactor, an enriched uranium heavy

Was Designed As a Spring Board for Scientific Effort

water system, a type which was in operation at Harwell. He must have been slightly influenced by the views of Sir John Cockroft. As a concession, he said we should have both types of reactors, but we all impressed upon him that we were not sufficiently advanced in manpower and other industrial facilities to have two high flux research reactors going. Discussions were heated and finally Dr. Bhabha gave in to our views and rightly so. I refer to these discussions to show how decisions were taken between himself and his younger colleagues and how Dr. Bhabha was willing to accept suggestions in spite of his own tremendous personal reputation.

REPROCESSING PLANT

With the starting of construction of the NRX reactor, a decision seems to have been taken (in which I was not involved) for setting up a Reprocessing Plant to process the plutonium produced in the CIRUS reactor. Even previous to this, a decision had already been taken to produce the fuel necessary for even half of the first charge of the CIRUS reactor. At this time, the Canadians were insisting on some sort of safeguards for the fuel that they were going to supply to us for this reactor. When it was pointed out that we could probably make the fuel elements ourselves, they wrote to us warning us that this was a very difficult metallurgical operation which had taken them considerable effort, but we were welcome to try and produce it but could always come to them in case we failed. From the tone of the letter, it was clear that they did not expect us to make fuel elements of the required quality and that we wou' ' eventually go to them for buying the fuel. Later, as it turned out, the fuel elements produced at Trombay were as good if not even better than the Canadian fuel elements. This event must be the first example in which our own technology established itself as being equal to that in the front rank of world technological developments. Our contributions to basic sciences have always been appreciated in knowledgeable circles over many decades, but of sophisticated technology developed independently of foreign help, this was certainly the first. Surely now our metallurgy and radio-metallurgy laboratories must be some of the best in the world.

No record of the developments of atomic energy in India will be complete without some references to the problems we had in getting the CIRUS reactor critical. A few days prior to the dedication ceremony, the reactor got into trouble in the sense that for some unknown reasons the cooling channel of the fuel used to get choked. This, as we discovered later, was due to bacteria developing because of local conditions in the water at our ambient temperatures. At that time, the Canadians were unable to identify the cause of the trouble and they left the reactor to us to set it right. The cause was identified by our biologists and chemists and suitable remedies were undertaken so that the reactor could function at its rated capacity of 40 MW. Since then, except for some minor problems for a very short period, the reactor has worked in an exceedingly satisfactory way. I must, of course, give due credit to the original designers of this type of reactor, the NRX, including many scientists of international repute such as Sir John Cockroft and W. Bennett Lewis.

A Nuclear Option

The setting up of the Reprocessing Plant at the same time when CIRUS became critical caused some eyebrows to be raised, for it gave India clearly a nuclear option. At the opening ceremony of the Reprocessing Plant, Shri Lal Bahadur Shastri offered this Plant to countries of South East Asia for reprocessing their fuel in case this was required. However, this has not been utilised by any of the countries. It was, however, made clear that the plutonium reprocessed in this plant, would be used for building future type of reactors, particularly fast reactors. The fast breeder reactor using plutonium is now a very important part of our programme.

It was getting clear to us that in our power programme we would be leaning on natural uranium heavy water systems, particularly as a result of Canadian experience and their generous offer to share the know-how with us. The CIRUS reactor was followed by the ZERLINA reactor (1961), which was designed to obtain Physics information on such type of reactors. It was built entirely by ourselves.

Whereas the programme of research reactors and its utilization was forging ahead, decisions were taken to develop all aspects of atomic energy for peaceful purposes. In fact the atomic energy programme in India at that time was designed to act as a spring board for modernising its scientific effort. A large programme of isotope preparation, sophisticated laboratories for studies in transuranium chemistry, highly specialised laboratories for Physics, particularly neutron physics, various aspects of solid state physics, solid state chemistry, preparation of pure materials were all established. An intensive programme on biological research including genetics mutation research, agriculture and medical research was also initiated in a very large way. This is by no means a complete list.

During the years 1955-60, while the *Apsara* reactor was set up and other important facilities were in the process of construction, it can be said that they constituted the "meat" required for setting up of an organisation. Besides this, it was during this period that the real foundation for a proper base in science was established in the country by a proper reorganisation of the administration, to make it more responsive to scientific research and the establishment of a training programme based on needs to provide for the necessary manpower. ●

Bhabha Centre Will Bring Innovation in Science Education

(Continued from page 3)

The BASE is now being consulted in matters relating to science education including syllabus, experimental facilities at schools etc. Workshops on improvisation of kits for school laboratories have been conducted by BASE in and outside Bombay. These activities may grow and future projects like the Science Museum for Bombay may materialise.

Bombay Municipal Corporation Project

While the BASE has been providing a medium mostly for extra-curricular scientific activity for school children, some scientists from the TIFR have been participating on a voluntary basis in the teacher-training programme of the Bombay Municipal Corporation (BMC). The opportunity to cooperate with the teachers was provided to them by the Physics Study Group of the All India Science Teachers' Association, which had developed some new curriculum material for Standard V and wanted to try it out. With the cooperation of the BMC, a three-year project was started to develop and try out new curriculum for Classes V, VI and VII in ten schools of the Corporation. Under the project, which was financed by the National Council for Science Education, orientation courses for teachers were held at TIFR in the summers of 1970, and the following two years. New curriculum material based on the 'discovery' approach, including kits of apparatus and text books have now been tried out successfully in these ten schools. A thorough follow-up programme, including regular visits to the schools by the resource personnel, and fortnightly meetings with the teachers, enabled the scientists to receive and incorporate feed-back from the teachers and the pupils to enrich the new material. Tests based on student performance and other aspects of their behaviour have demonstrated the success of this programme.

The trend-setting nature of this programme is encouraging. The new

A teenage scientist attends to his exhibit at an Interschool Science Exhibition in Bombay.

programmes at Hoshangabad and the Kishor Bharati in the rural areas of Madhya Pradesh are based on the experience of the BMC-TIFR project. It may be pointed out that the Kishore Bharati Project is organised by Dr. Anil Sadgopal, a scientist from TIFR who so keenly felt his social responsibilities that he left TIFR to undertake this project. A similar project has been launched in Attara in U.P. by scientists from I.I.T. (Kanpur). These projects are showing the feasibility of the 'discovery' approach even in the rural setting and for the first-generation learners. The Government of Madhya Pradesh has collaborated in a programme to upgrade the curriculum leading to degrees and diploma in education.

Science Films

Another prime concern of the science educationists today is spreading of scientific literacy among the school and adult population, and to supplement the activities of the teacher so that he can be effective in his own environment. They have collaborated with the Space Applications Centre, Ahmedabad in a programme for producing science films for this purpose. One such film has been produced already. These films, to be shown on satellite-TV, will, hopefully, help in increasing the scientific literacy in India.

The Homi Bhabha Centre for Science Education

Encouraged by this success, it w felt that a Centre should be establishec in TIFR to institutionalise these voluntary efforts. This was made possible by support offered by the Sir Dorabji Tata Trust. An ad hoc grant was also received from the National Council for Educational Research and Training. It was only appropriate that the Centre be named after Dr. Homi Bhabha, the prime architect of organised research activity in our country.

The Homi Bhabha Centre for Science Education, which was inaugurated by Prof. A. N. Namjoshi at a function held at the Homi Bhabha Auditorium on July 2, 1974, will try to provide intellectual leadership in generating highly innovative programmes in science education. Apart from contributing to the general R & D in this field, the Centre will undertake the specific task of generating new and relevant curriculum for the entire school system. Besides these immediate tasks, work needs to be done to understand how children learn in a large variety of backgrounds in which they grow, to develop and test new methods to train teachers effectively, and to make proper use of powerful media for mass communication, such as the TV, to help the enormous population of first-generation learners. ●

NUCLEAR INDIA

is a monthly publication of the Department of Atomic Energy, published around the 20th of each month. To ensure prompt attention, all communications should be addressed to the Editor, NUCLEAR INDIA, Department of Atomic Energy, Chhatrapati Shivaji Maharaj Marg, Bombay 400 039. While intimating change of address, the code and number given on the wrapper should be mentioned. Bombay recipients may contact 25 04 77 for prompt action.

Edited and published by Jagannath Sharma, Publications Officer, Dept. of Atomic Energy, Government of India, Chhatrapati Shivaji Maharaj Marg, Bombay 400 039, and printed by him at Printwell, Mahalaxmi, Bombay 400 011.

Registered No. R. N. 9002/62